Is There a Science of Instrumentation?

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INSTRUMENTATION, as the word is used here, means the development and application of measuring devices which respond quantitatively to some physical property of a situation and give an output which depends on this property. The word instrument is often used in a broader sense, as when forceps are referred to as surgical instruments, but in this discussion it refers to measuring devices.

Nearly all of the progress of modern science and industry is directly traceable to the development and use of a wide variety of measuring instruments. With monotonous regularity people who discuss this subject quote Lord Kelvin's saying to the effect that one's knowledge of a subject is of a poor kind indeed unless one knows how to measure quantitatively the factors involved. Quoted often enough so that it now has the status of a cliché, this saying is nonetheless true.

With all this appreciation and understanding of the importance of measurement, the problem of devising suitable measuring instruments for use with different quantities and in different situations has, up until recent times, been left pretty much to individual scientific specialists to work out as best they can. But in recent years, especially in the past decade, it has come to be more and more widely recognized that the problems met in designing various kinds of instruments have a great deal in common. Because of the importance of these common elements there is a useful body of general doctrine and data which can be termed the science of instrumentation. Recognition of this fact has found expression, for example, in the founding and growth of the Instrument Society of America. The society is devoted to this over-all point of view on the design of measuring instruments—not on such an abstract philosophical basis that no particular results are attained, but rather in practical terms whereby the designer of an instrument for a particular purpose can derive maximum benefit from experience gained from other instruments which have been built, perhaps, for quite unrelated purposes.

This trend deserves to be more widely known and cultivated among scientists as a whole. Too often it happens that a man confronted with a measurement problem requiring instrumentation is such a specialist in the phenomena being studied that he is unacquainted with the mechanical, electrical, and optical design principles which enter into good design of his instrument and is impatient with them. He then works out a "gadget" to fill his needs as best he can and in many cases it depends greatly on the happy ingenuity of his machinist or glassblower. What the science of instrumentation is trying to do is to codify general principles and design data referring to instruments as a whole so that their design can itself be put on a scientific basis worthy of the scientific problems it is to help solve.

Instruments may be classified first as to whether the objects whose property is to be measured are discrete or continuous. For example, an instrument that measures the capacitance of a large number of small condensers, one by one, is measuring a discrete property, and one that indicates changing hydrostatic pressure is measuring a continuous property. Evidently all instruments of the discrete class have a great many problems in common with regard to the mechanism for feeding in the objects to be measured, independently of what quantity is measured, and the same is true of all instruments responsive to a continuous variable.

Of the instruments for discrete measurement, perhaps the simplest is that which merely counts the total number of events or objects to which it responds. In nuclear physics it has been necessary in recent years to develop electronic circuits capable of counting objects at very rapid rates. In these the object or event is made to give rise to an electrical pulse fed to a scaling circuit and eventually to a mechanical register. Such techniques will undoubtedly find application in many other fields, such as in counting blood cells in a blood sample and in automatic digital computing machines.

Second, an instrument can be classified as to the nature of the element in it which is sensitive to the quantity to be measured and the nature of the response made. Such a sensitive element is known generically as a *transducer,* since it changes a physical quantity of one kind into another. For example, temperature measuring devices are made which depend on (a) the differential expansion of two solids, producing elastic deformation of them, (b) differential expansion of a solid vessel and a contained liquid, producing relative motion, (c) change in electrical resistance producing an electrical output signal, and many others.

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At first sight it may seem that the sensitive elements used for different quantities are so various as not to have much in common. If this were so there would be no general basis to the science of instrumentation. But it is not so. Every sensitive element gives some kind of output quantity Q (such as a linear motion to be observed visually or an electrical voltage to be dealt with appropriately in another part of the instrument). Let x be the physical quantity to be measured. It is a general characteristic of all responsive elements that they possess properties that need to be considered in design of an instrument independently of the physical nature of x and Q. Among these are (a) *sensitivity,* the quantity $Q'(x)$, giving the rate of change of output with change of input under steady equilibrium conditions, (b) *unsteadiness,* the measure of the fluctuation in output $\overline{(Q-Q_0)^2}$ given by the transducer under a steady value of x due to looseness and erratic disturbances inherent in the situation, (c) *sluggishness,* the measure of the time rate at which Q assumes its new equilibrium value Q_1 from the value Q_0 when x abruptly changes from x_0 to x_1, and (d) *hysteresis,* which is a shortcoming of some transducers whereby Q is not dependent on x alone but on the past history of all values earlier assumed by x, and (e) *permanence,* the quality whereby $Q(x)$ retains its constant functional form over a long period of time whether the instrument is in use or not, thereby maintaining the instrument's calibration.

Evidently the design principles involved in specifying these characteristics of a transducer are quite general and will have similar limiting effects on the performance of the instrument no matter what the nature of Q and x. And as soon as we are past the transducer, evidently, we are dealing with the physical quantity Q instead of x. Hence from here on the design principles involved do not depend in any way on the physical nature of the quantity to be measured. In passing it may be remarked that sluggishness is not always an undesired element in a transducer, for sometimes the quantity which it is really sought to measure is not really variation of x at each instant, $x(t)$, but some sort of moving time average like

$$\bar{x}(t) = k \int_{-\infty}^{0} e^{-k(t-\tau)}\, x(\tau)\, d\tau$$

which is based essentially on the values of x in the past for a time of the order of $1/k$.

The next essential part of the over-all instrument may involve some sort of further transformation or amplification of the transducer output Q, as when the optical image of a linear movement is projected with enlargement on a screen, or when an electrical voltage is passed through a transformer. Evidently the design data for such devices will depend solely on Q, not at all on x, and therefore will be the same no matter in what branch of science or technology the instrument is to be applied.

The last part of the instrument involves the transformation of Q into some sort of indicating, recording, or control mechanism, depending on the use to be made of the data the instrument provides. Where indication is desired for individual readings or continuous observation, the coupling to the observer's sensory equipment is usually made through the sense of sight. Usually the indicating device involves the motion of a pointer relative to a scale, the position being noted visually by the observer. This led Eddington to regard all science as the systematization of relations between pointer readings obtained in various ways. This favored position of the sense of sight arises from its great sensitivity and resolving power. But one could also devise instruments in which, for example, the output, dependent on the quantity to be measured, controlled the pitch of a sound heard by the observer.

The transforming and amplifying elements of an instrument, as well as the indicating elements, need to be judged according to the same kind of qualities as were listed for transducers. In the over-all analysis there is nothing to be gained, for example, in having very little sluggishness in the transducer if the indicating element has much sluggishness.

A particularly simple kind of indication is that of the "go—no go" variety, which simply gives a signal if x is greater or less than preassigned limits or lies outside a preassigned range.

A recording mechanism is an element that gives a material record of the variation in x observed by the instrument. This is usually in the form either of a continuous curve drawn on a strip of paper or of a discrete series of digital numbers stamped on a strip. But it need not take either form and might be a magnetized tape with the output coded on in some way. Such a form would be applicable where some computing needs to be done on the output data by an automatic computer arranged to accept data on a magnetized tape as its input. The design considerations involved in a recording mechanism may be quite independent of the nature of the quantity x that is being measured.

Finally, a control mechanism is an element that takes the output, which may also be given presentation by an indicator or recorded in a recorder, and uses this to actuate some device in the original situation affecting the value of x. In the simplest case it is desired to have the control mechanism provide a situation which leads x to assume a constant value.

But it is only slightly more complicated to require that x follow some preassigned functional variation with time. Here all sorts of new problems present themselves, such as the tendency of the system to "hunt," that is, for the correction action brought into play by the control to produce greater effects than needed to bring x to the control value $f(t)$.

In more complex cases there may be more elaborate combinations of the basic instrument elements, as when several transducers respond to several quantities $x_1, x_2 \ldots$ and the signals so obtained are combined mathematically in some analogue or digital computer to produce one or several output quantities $z_1, z_2 \ldots$ which may actuate a control mechanism. Also it may happen that the output does not actuate a control mechanism related to the system being measured but actuates another device which maintains a prescribed relationship to that system. Thus, a gun director's input is optical or radar data about position of a target, but its output does not act directly on the target to control that position, but on a gun with the object of aiming it so as to launch a projectile which will hit the target.

Enough has been said to bring out the fact that in modern complex instruments a large part of the instrument is independent of the nature of the quantity to be measured. It is this fact that is giving rise to the recognition that there is a science of instrumentation concerned with these common elements and their systematic study and improvement. It seems quite likely that the instrument scientist will in the future play a role of steadily increasing importance in the development of all the sciences. It is a profession that should lend itself to specialization and workers in all fields should be relieved as much as possible from the distraction of having to devote too much attention to the detailed design of instruments for their particular needs.

In accord with these general ideas, the National Bureau of Standards is planning a program that will give just this kind of over-all study to the basic problems of instrumentation in all the physical sciences. Up to now, corresponding to the older and still common practice, instruments have not been considered from the general viewpoint, but separate and uncoordinated attention has been given to mechanical, optical, electrical, and electronic instruments in different parts of the organization. The program is being planned in cooperation with the Office of Naval Research and with research groups in the Army and the Air Force.

The objectives of this program are three: (1) systematic analysis of available methods and devices in terms of their precision and reliability; (2) studies of materials, components, and elements which are now known to impose serious limitations on instrumentation; and (3) development of specific instruments not now available.

Under the first heading, as part of the process of reviewing the literature, some particular limited field in which specific instrumentation problems are of interest will be studied. Careful analysis at this stage of how related measurement problems were solved in the past, of available related instrumentation, of its precision, and of the materials involved, will establish a basis for actual development work and provide critical data on the status of instrumentation in this field. Over a period of years, this approach should not only yield the concrete instruments needed—a need determined in this case by the cooperating agencies—but also accumulate information in a systematic manner, permitting a logical approach to subsequent problems.

Present demands for instrumentation improvement are essentially twofold: higher sensitivity and faster response. These are necessary because the time intervals with which present day work is concerned are extremely small, only minute displacements may be allowed, and the signals are low in power. In general, sensitivity can be increased if the time during which phenomenon is under observation is increased, but this often cannot be done because the existence of the phenomenon may be of short duration—as in, for example, nuclear and cosmic physics and in the study of biological cells. At the same time, noise level becomes a serious limiting factor where signals are weak.

In spite of these incompatible objectives, instrumentation is succeeding in extending sensitivity and signal response, but in the process large quantities of complex data are the result, creating the problem of processing such information. Here other instruments, whose functions are the orderly and integrated presentation of data, are needed. Recording devices are typical of this class of instruments, but more sophisticated types are necessary now for the analysis of large amounts of data, the performance of predetermined operations, and the presentation of the summarized findings, discarding unwanted background. Fortunately, machines like electronic digital computers, originally planned for solving mathematical equations, afford a means of attaining this end. Specific problems to be considered in the program of the National Bureau of Standards include transducers, electron optical field mapping, data transmission and reduction, improved microscopes, and so on. Work on some of these is already in progress. Coincidentally, the bureau's program in electronic digital computers

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is continuing: two machines are under construction in its laboratories in Washington and Los Angeles, while another five are being built by contract with private laboratories and industries.

One aspect of instrumentation, already mentioned, is the problem of materials and components. Related to this is the existence of principles of measurement whose application cannot be realized until developments in another field of science are achieved. Thus, electron optical field mapping represents an application of principles in optics to electronics, yet the realization of this important research tool had to wait until the science of electronics had advanced to its present state. An illustration of the dependence of instruments on materials is the wire strain gage. The principle was known as long ago as Ohm's law. Yet it was not until Simmons, Ruge, and De Forest developed methods of bonding the wire to paper and ways had been found to measure and record small changes in current that the principle was applied successfully. It is for these reasons that the study of materials and components, as well as the study of past methods proposed for measurement problems, is an integral part of the bureau's program.

The need for cross-channelling information in the sciences has grown acute in recent years. When it comes to instrumentation, this need has two aspects: basic developments in one field may provide the basis for instrumentation in another field and instruments developed in one field may have applications in others. As an illustration of the first aspect, scientists in the bureau's radio propagation laboratory recently developed and constructed an atomic clock which has remarkable precision. The heart of the development is the application of the knowledge of reasonance absorption in atomic physics and of microwave radiofrequencies to the problem of time. Again, the bureau has developed a standard of length based on the green line of mercury 198. This development depended on knowledge of atomic and nuclear physics, while the realization of the instrument and associated apparatus is a combination of knowledge in electronics and optics. An analogous story could be told about the recent measurement at the bureau of the magnetic moment of the proton. Here there is, at least in part, with excellent possibilities for full development in the future, the basis for atomic standards of the three basic measurements—time, length, and mass.

Indicative of the importance of cross-channelling information concerning instruments is the bureau's experience with diamonds as tools for measurement. Many years ago the bureau was interested in diamonds for ruling lines on precision scales, and devices and methods for cutting diamonds were successfully developed. The same group of scientists devised a diamond indentation method of hardness testing, which has been standardized and is used in the Tukon tester.

In the course of this work, scientists engaged in the study of aircraft cylinder wear, who had been using conventional measurement methods, recognized the possibility of determining cylinder wear by the change in length of a series of standard indentations, using diamond indentation. Modifications were needed, and a special instrument was developed capable of measuring wear to a precision of 0.00002 inch and of detecting even smaller amounts. Auxiliary developments continued in such fields as the cutting of diamonds and the drilling of small diamond dies for fine wire production.

These examples not only indicate the need for wide dissemination of information among the fields of science but reinforce the concept that instrumentation is a science in its own right. There is no reason why the practitioner of this science, conceived of as the logical approach to measurement problems, cannot provide measurement devices of a given type for a variety of fields. Certainly this would save the experimentalist much time and effort. Prior to this century, an analysis of the experimentalist's activity might have shown that the bulk of his time was spent in getting ideas and in analyzing the data of his subsequent experiments while a minimum of time was spent in the construction of instruments. In the present period, too often the scientific situation is such that the bulk of his time has to be spent in devising and constructing his instruments. From the point of view of research, this is unfortunate; and it is here that the science of instrumentation can make significant contributions not only to instrumentation as such but to the progress of original research.

Operational Aspects of Instrument Design

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Of wonders of science and feats of design
Has many a scribe writ the praise;
And if I now mention the subject again
It's distinctly a relative phase
For while science and gadgets are fine in their ways
One worries at times 'bout their clutch,
Especially when science, design, and math'matics
Combine to get us in Dutch.

THE AMAZING RELIANCE today on implements and machines, particularly on those trust in what they do or tell us were well we term *instruments*, and our unquestioning described a few years ago by Hugh L. Dryden, then associate director of the National Bureau of Standards (now director of aeronautical research, National Advisory Committee for Aeronautics) in an address before the Instrument Society of America (*2*):

> A significant, astonishing, and typical phenomenon of modern times is the general confidence placed in the readings of any well-constructed instrument. The automobile driver swears by his speedometer; the housewife looks at the thermometer to see whether she ought to feel too warm or too cold; the handsomely ornamented dials in the lobby of the skyscraper convincingly prove that the wind is blowing 60 miles per hour from the northwest on the roof. Even engineers who should be more skeptical have contracted the habit of relying on the readings of instruments. This naive faith has in general been justified by the care which the instrument industry has exercised in the control of the accuracy of its products. Nevertheless, this great faith in the readings of instruments should continually remind us of the responsibility resting upon us to justify that faith, to make more accurate instruments, which hold their calibration under severe conditions of service, and which are most nearly foolproof in operation. We have an obligation to promote the correct use of instruments in a manner to secure uniformity and mutual understanding.

Dr. Dryden justly stresses our indebtedness to the instrument industry for the care it "has exercised in the control of the accuracy of its products." He does not mention, however, either in the passage quoted or elsewhere in his address, the enormous influence exerted upon the instrument industry by the mass experience of the many users of instruments produced in quantity and employed under a great variety of conditions—a mass vote that expresses experience so vast that even the improbable has plenty of chance to occur and usually does. If the design of an instrument released today is faulty in even the slightest degree, you hear about it tomorrow, or at most, the day after tomorrow. It is this combination of mass vote registering a vast experience and a demonstrated manufacturer's responsibility that justifies our faith in these instruments.

In the case of instruments of which only a few are produced, and of instruments (e.g., military contrivances) produced in quantity for use under extraordinary conditions that are difficult or impossible to simulate, our trust in the instruments rests on less firm foundations—it rests largely on extrapolation from commonplace experience bolstered by faith in the manufacturer's ability to design and produce an instrument that will do the job intended under the conditions of actual use. When the designer and producer of the instrument are far removed from the ultimate user not only geographically but also in experience and perspective, too often the case and sometimes unavoidable, then our faith may be really unwarranted.

The more complicated the instrument, the severer or stranger the conditions of use; the less we know about the eventual operator of the instrument, the more acute are the problems of instrumentation. While these problems do occur in the design of laboratory instruments, they are more frequently critical in the design of control devices—instruments which measure the values of a number of variables (with or without the intervention of a human operator) and which react in a predetermined manner to establish a prediction for control purposes.

An excellent example of the difficulties which the Operational Analysis Groups of the Air Forces encountered was the first group of automatic sights of World War II, designed for the defense of bombers against fighters. From the strictly instrumental point of view, which necessarily precluded field studies, these computing sights were clever mechanisms for determining the amount of deflection required (a "lag," not a "lead," when the fighter was following a pursuit-curve course toward the bomber). The computation was based on the observed angular velocity of the fighter relative to a coordinate system based on fixed directions within the sight's mount, which was firmly fastened to the bomber's frame and not gyro-

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stabilized. The component of this relative motion pertinent to the deflection problem is the motion of the fighter relative to a coordinate system determined by the velocity vector of the bomber, the vertical plane (i.e., the plane through the zenith and through the bomber's velocity vector), and the plane through the bomber's velocity vector perpendicular to the vertical plane (which will be horizontal if and only if the bomber's velocity vector lies in the horizontal plane). Unfortunately, as a result of the pitching, rolling, and yawing of the bomber, there is generally considerable motion of the sight-mount coordinate system relative to the coordinate system determined by the bomber's velocity vector. This motion is, of course, irrelevant to the deflection problem. Consequently, in the absence of gyrostabilization of the sight mount or an adequate "smoother" within the computer to iron out the irrelevant components of motion, these sights merrily computed deflections with comparatively great exactitude but on the basis of largely irrelevant data. It didn't take experienced gunners long to discover this fact in actual practice. As a consequence these computing sights were torn out of the bombers in the combat theaters, and for a time the whole program of development of automatic computing sights for aerial warfare was seriously discredited.

Here there were remedies available to the instrument designer—gyrostabilization of the sight mount, a built-in smoother, or both—but cases do exist where uncontrollable external conditions limit the realizable precision of a high precision instrument to a far greater extent than do the more evident limitations on the design parameters involved. A case in point is the optical range finder (*2*). In effect, this instrument measures the angular parallax, α, of the target when viewed from the two ends of a base of length b contained within the instrument, the scale of the instrument is graduated to read range, r, directly, and the graduations are based on the equation $r = b/\alpha$, where r and b are in the same units (e.g., feet, yards) and α is in radians. An error of $\Delta\alpha$ in the measurement of the parallactic angle produces, therefore, an error of $-(r^2/b)\Delta\alpha$ in the measured range. Range finders have been built with base lengths as small as 20 inches and as great as 100 feet. Turret range finders on battleships have base lengths of 50 or 60 feet. A typical American instrument for use against airplanes has a base length of 13½ feet. The ratio of the range to be measured to the base length is generally so large that satisfactory accuracy cannot be obtained unless the parallactic angle can be measured with an error not greater than two or three seconds of arc. To lessen the errors due to the limited acuity and resolving power of the eye, range finders are usually equipped with an eyepiece of magnification M, the effect of which is to transform α into $M\alpha$ for purposes of measurement. Thus an error of δ in the apparent angle so measured becomes an error of δ/M in α. From this error relation and the basic one given previously relating errors in α to errors in r, it would seem, and it has often been tacitly assumed, that an increase of magnification by a given factor, or an increase in base length by the same factor, would be equally effective in increasing the precision of the instrument as a *range* finder; and that by sufficiently increasing the magnification, or the base length, or both, any desired precision in terms of *range* could be achieved. Unfortunately, convection currents in the air between the range finder and the target—there is always some quiver and sometimes a veritable "boil"—invalidate these conclusions. From studies conducted under the auspices of the OSRD during World War II and some more recent investigations carried out by F. E. Washer and his associates at the National Bureau of Standards, it now appears (*2*) that any single measurement of the parallactic angle, α, has a standard deviation component, perhaps between 0.80 and 1.20 second (1 second = 0.000005 radian), that originates in the air path between the range finder and the target, and consequently is beyond the control of the instrument designer. By substitution in the basic error relation given earlier, the corresponding standard deviation component of a range estimate of a given range using a particular base length can be determined. Thus, taking 1 second as a typical value of the standard deviation component (due to shimmer) of a measurement of α, the corresponding range standard deviation will be 1 percent if the range is 2,000 times the base length and 5 percent if it is 10,000 times the base length; and this amount of uncertainty will be present even if the range finder and the observer contribute no additional components of error (a purely hypothetical situation!). The instrument designer can offset this component of error only by making the base long enough to achieve the precision required at a given range, if practical considerations will allow him to do so.

Up to this point we have considered only cases where "external conditions" in themselves prevent full realization of the built-in accuracy and precision of the instrument. Let us now consider some instances where the human operator of the instrument is the stumbling block. These human troubles can be of two kinds: *physiological* and *psychological*. In the case of the optical range finder the limited resolving power and limited acuity of the observer's eye are physiological limitations. The limitations of coincidence judgment produce a standard deviation component

in the *apparent* field, perhaps of the order of 3 seconds. In terms of the measurement of the parallactic angle, α, this becomes a standard deviation component of $3/M$ second. Combining this with an air-path component of about 1 second, as just considered, the contribution of these two sources of error to the standard deviation of measurement of the parallactic angle, α, is $\sqrt{1+(3/M)^2}$, which for commonly used magnifications of 8, 12, and 24 diameters equals 1.068, 1.031, and 1.008 seconds, respectively. From these figures it is evident that the air-path component completely dominates the situation, and that by using readily accessible magnifications the contribution resulting from the aforementioned physiological limitations of the observer can be rendered negligible. Unfortunately, this is not the whole story, for use of high magnifications introduces a psychological difficulty in the form of observer frustration resulting from the shimmy of the target image—the quiver of the target (as seen through the air path from the range finder to the target) *magnified M times* by the lens of the eyepiece. Indeed, if the magnification involved is 20 or 24 diameters and the air path is "boiling" vigorously, which is the situation on hot days, the observer may be unable to "observe" at all, that is, unable to bring the target image and the reticle of a stereoscopic range finder (the two target images of a coincidence range finder) into "coincidence."

A strictly psychological difficulty arises in connection with the *stereoscopic* range finder. In making a setting with a stereoscopic range finder the reticle and target are brought into coincidence by turning the range knob. "If . . . the target is extended or against a background so that there is no free space on either side of the target, then when the reticle is projected beyond the surface of the solid object the observer is loath to accept the apparent penetration of the reticle into the solid target, and hence a bias is introduced which may correspond to a large error in the indicated range. Similarly, when one attempts to set a crisp, sharply defined image of the reticle in stereoscopic coincidence with a target not sharply defined and obscured by blue haze, the pronounced difference in atmospheric perspective leads to an erroneous setting. These errors resulting from biased stereoscopic judgment may amount to as much as five or six seconds [in the measurement of the parallactic angle, α]. If one attempts to check the graduations on the scale of a range finder by reading ranges on a selected series of terrestrial targets at known distances, the stereoscopic bias for the different targets will, in general, be different for the different targets, giving a jagged calibration curve which suggests that individual graduations on the scale are displaced from their correct positions in a nonuniform manner. The falsity of this conclusion can be shown by testing the range finder with a better planned test in which stereoscopic bias is eliminated or equalized for the different targets" (*3*). The seriousness of this psychological source of errors is readily appreciated when it is recalled that satisfactory range measurement generally requires measurement of the parallactic angle with an error not greater than two or three seconds. Fortunately, there is a design trick (*2*) used in the German R40 range finder whereby bias from this source can be averaged out by making two settings on the target, and this may be used for range reading on stationary or slowly moving targets.

The automatic computing sights mentioned earlier were plagued also with operator errors of psychological, or psychophysical, character arising from the interaction of the operator and the instrument. In the first place, the several motions the operator had to perform were somewhat unfamiliar and awkward, and cultivation of adequate skill by intensive training was necessary. With one type of these devices the operator moved the gun mount (upon which the sighting mechanism was firmly fixed) in azimuth and elevation by means of a handle-bar arrangement, one handle of which contained a pistol-grip trigger for activating the gun(s), while rotation of the other handle adjusted the range setting of the sight. It was difficult enough to learn how to perform all of these motions correctly to begin with. To be called upon to perform them correctly in the excitement of an attack, lasting 5 seconds or less, was asking too much! (How many persons can *pat* their heads, *rub* their stomachs, and *scratch* a stomach itch all at once, without getting mixed up? The gunner's problem was even worse!) To make matters still worse, the reticle of the sight was controlled by the computing mechanism and was not under direct control of the gunner—the most amazing changes of position of the sight reticle would result at times from a simple movement of the hands.

There exists today, largely as a result of such wartime experiences, a branch of applied science known as *human engineering* (called by the inner circle "psychophysical systems research") that is actively concerned with "man as a worker of machines, and with machines as things that man must work." This aspect of instrumentation deserves close attention from both designers and users of instruments.

Although the instrument in hand may be able to perform its intended function with great accuracy and precision, this built-in accuracy and precision may be highly illusory in terms of the uses to which its end product are to be put (e.g. measurements for direct use as such in scientific research, engineering tests,

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and so forth; or measurements constituting the stimuli activating an automatic control device). Thus high speed punch card equipment is fine for processing statistical data to obtain accurate summary figures with ease and rapidity. But the trustworthiness of these summary figures for purposes of administrative action or scientific inference depends upon the trustworthiness of the raw data themselves for these purposes, which in turn hinges upon the extent to which the method of obtaining these data effectively produces random samples from the population to which the conclusions are to apply. The capabilities of these machines, which bring the processing of very large amounts of data within the realm of practicability, carry with them the danger of diverting attention from the need for considering carefully in the planning stage of an investigation (a) exactly *what kinds* of data are required for the purpose at hand, (b) *how* they are to be collected, so as to assure validity for this purpose, and (c) in *what quantity* they will be needed in order to achieve adequate precision. The approach "Let's record everything in sight and the machine will do the rest" is not to be recommended, for when the data are in and are partially or fully analyzed it is too often found that "everything in sight" failed to take account of factors critically affecting the value of whatever conclusions might be reached.

Finally, the great practical value of many instruments stems in the last analysis not so much from the high precision of individual observations thereby attainable as from the fact that they make it possible to obtain broad coverage with observations of ample precision. For example, consider the core-boring instruments and associated techniques developed by the Bureau of Customs and others for evaluating the clean-wool content of a shipment of baled wool. In the case of many carpet wools the relation between the between-bale and within-bale components of variation of the clean-wool content is such that accurate evaluation of the (average) clean-wool content of the entire shipment requires the sampling of many bales, taking adequate amounts of material from each bale sampled. This is made possible by the core-boring tool. Without it, the cost of obtaining the same intensity and coverage of sampling by breaking open the bales and drawing samples by hand would be prohibitive and would necessitate relaxing accuracy requirements below levels considered desirable. As another illustration, consider the Magne-gage designed at the National Bureau of Standards to measure the thickness of nonmagnetic coatings on a magnetic metal object. By its use the total thickness of composite coatings ranging from 0.0005 to 0.003 inch can be determined rapidly and nondestructively to within about 10 percent; and the thickness of each component layer of similar coatings, to within about 15 percent. The important feature is that the determination is nondestructive and rapid, so that many different parts of the coated object may be examined when the quality of a coating or the effectiveness of a coating technique is being evaluated.

To sum up: From prehistoric times man has been a user and developer of tools. Man now depends more than ever on implements and machines—some crude, many elaborate; some delicate, others sturdy; all the servants, and some at times the masters, of man. Thomas Carlyle said: "Man is a Tool-using Animal. . . . Nowhere do you find him without Tools: without Tools he is nothing, with Tools he is all" (*1*).

But if our instruments are to serve their purposes fully—and this is especially true of modern, complex control devices—both the designer and user must never forget (1) the conditions of operation, (2) the nature of the measured quantities, (3) the relation of these quantities to the end action, and (4) the psychological and physical characteristics of the operator. With these elements in mind, instrumentation will progress, providing man with ever-increasing extension of his senses and control over his environment.

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Reports of Meetings on Instrumentation

The Fourth Annual Conference and Exhibit of the Instrument Society of America

W. A. Wildhack

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Sixty-five technical papers presented at 23 sessions, five cooperating societies; 8,000 in attendance, 150 exhibitors showing $6,000,000 worth of new or improved instruments, components or accessories, spread over 20,000 square feet of the huge Municipal Auditorium in St. Louis—these are the bare statistics of the week-long conference and exhibit of the Instrument Society of America, held September 12–16.

One of the youngest and fastest growing of the technical societies, the ISA brought together at St. Louis, in this field of common interest, several other scientific and engineering societies. The Industrial Instruments and Regulators Division of the American Society of Mechanical Engineers had two sessions; the American Institute of Electrical Engineers two; the American Institute of Physics two; and the National Telemetering Forum two. Members of any of these cooperating groups (or the Institute of Radio Engineers) were admitted without charge to all sessions, as well as to the exhibits.

In general, the problems of measurement and control in any branch of experimental science or industry require for their solution the design, development, selection, adaptation, procurement, understanding, and use of measuring devices and techniques. This, broadly, is the field of instrumentation, the art and the science of measurement and control. The promise of this newly recognized branch of applied science lies in the universality of its contributions—it is an indispensable and integral part of all of the specialized sciences, and any discovery or improvement of devices and techniques for measurement and control of any physical quantity can find immediate application in many unrelated specialties of science or engineering. Its strength lies in the universality of its sources of progress—the operating principles of measuring devices are drawn from all the basic fields of science, and any discovery or advance in any field is likely to find eventual or immediate application in a new or improved device for use in still other fields.

Within the last decade or two, the growing complexity of science and technology has made it impossible for the engineer or scientist to keep abreast of instrument developments and measuring techniques in other fields. Hence, the emergence of the new science of instrumentation and its practitioners, specializing in cutting across specialties and cross-fertilizing all the sciences.

The Society. The ISA was formed in 1945 as a combination of a number of local instrument societies in various centers of industrial or scientific activity, and now has 34 sections in the United States, two in Canada, and one in Netherlands West Indies, with a membership of over 3,000.

The objective of the society is "to advance the arts and sciences connected with the theory, design, manufacture and use of instruments in the various sciences and technologies." The various sections hold regular meetings and national meetings are held twice yearly: the spring meeting for a one- or two-day period, and the annual conference and exhibit for five days, during the first half of September. The location changes each year. The society publishes the *Proceedings*, containing papers presented at ISA sessions during the annual conference, and also edits a special "Journal" section of the monthly magazine, *Instruments*, which each member receives. Special publications are proposed by the working committees of the society, of which there are more than a score. ISA officers for 1950 are: R. Piggott, president; A. O. Beckman, J. B. McMahon, Nelson Gildersleeve, and Porter Hart, vice presidents; Hugh Ferguson, treasurer; and Richard Rimbach, executive secretary.

The Conference. Conferences are much alike, whether the papers relate to star spectra, enzymes, or automatic control. People drift in and out, talk to colleagues in the halls, ask a few questions on the floor, and grill the speakers later in small groups.

The ISA papers were available in preprint form, which made for better discussion. There were sessions on maintenance and operation, inspection and gaging, instrumentation for production processes, transportation instruments, instrumentation for testing, and analysis instrumentation. A symposium was held on rockets and jets and a number of papers in the session on instrumentation for testing related to the currently "hot" problem of testing rockets and jets. Speakers at all sessions were allowed at least twenty minutes, and in some sessions up to an hour. Attendance ranged from one hundred to four or five hundred. Some of the papers were summarized especially for *Science* by the authors and are presented elsewhere in this issue.

At the annual business meeting a paper was presented on "Instrumentation Flow Plan Symbols," by David E. Hostedler (Foster-Wheeler Corp., New York), as illustrating outstanding work done by a subcommittee of the Recommended Practices Committee.

On the weekend preceding the conference, the ISA, in cooperation with a number of manufacturers, sponsored an "Instrument Maintenance Clinic" for instrument technicians, which proved extremely popular. The conference sessions on instrument maintenance and operation were also well attended. A panel discussion was held on "Instrument Mechanic Training."

The Exhibit. The hundreds of instruments and components displayed or demonstrated at the exhibit received

careful inspection and study from the engineers, scientists, technical men, purchasing agents, and industrialists in attendance.

No catalog of the products displayed could convey the educational value of the exhibit. The variety of exhibits precluded any monotony: miniature ball bearings, large 10-in. control valves, recording spectrophotometers, glass thermometers—any of those might be found in the booth next to electronic vibration devices, or an X-ray diffraction equipment.

The big manufacturers of indicating and recording instruments were all represented by large displays. The large number of control components and instruments reflected the fact that the process industries (chemicals, petroleum, metals, etc.) furnish the largest base for the instrument industry, and for the membership of the ISA.

Significant of the role of advanced instrumentation in industry was the showing of soundly engineered commercial products such as the recording spectrophotometer with nearly 100% automaticity, supersonic generators and materials testing devices, computing mechanisms, X-ray diffraction equipment, etc., which only a few years ago were new in the research laboratory, as rough experimental models.

Instruments for measurement and control of flow, temperature, time, and chemical concentration, were much in evidence. But electronic, radioactive, geophysical, and mechano-electronic devices were also shown in profusion: the mass spectrograph leak detector, vibration pickups, roughness indicators, accelerometers, etc.

Various agencies of the government had been invited to participate in the exhibit. The Department of the Navy was represented by the Bureau of Ordnance, the Naval Ordnance Laboratory, the Naval Ordnance Test Station, and the Bureau of Aeronautics. The National Bureau of Standards also had an exhibit. One of the most striking Navy exhibits was a radio tracking equipment (Raydist), recording in the booth the location of a boat cruising up and down the Mississippi, carrying a transmitter. Another was an X-ray planigraph, in which the object being X-rayed was oscillated in a complicated motion during exposure. The resulting picture showed clearly the details of structure in a certain selected plane within the object.

It is to be hoped that, in the future, participation of such agencies as the Public Health Service, the Atomic Energy Commission, and the Bureau of Reclamation will be obtained, to bring the instrument developments in these fields to the attention of the technical public and give stimulus to joint attacks on special measurement problems.

Participation of manufacturers of biological and medical equipment might be increased by arranging some joint sessions with the American Medical Society, perhaps, or the American Physiological Society. The problems of measurement in the study of the human body and its ills, in physiology, and in biology generally, may be sufficiently specialized, and are certainly sufficiently important, to justify inclusion of these fields in the area of cooperative effort of the ISA.

But the society, and the exhibit, are new: they will develop, and will emphasize, those fields in which the greatest interest is found. Each member of the AAAS who can do so should attend future ISA exhibits and participate in its conferences.

The 1950 conference will be held next September in Buffalo, N. Y.

Fourth Conference on Low Temperature Calorimetry

Daniel R. Stull

Dow Chemical Company, Midland, Michigan

The Fourth Conference on Low Temperature Calorimetry was held in Cambridge, Massachusetts, on September 10, during the meeting of the International Conference on the Physics of Very Low Temperatures. Both conferences met at the Massachusetts Institute of Technology and, because of the similarity of interests, each conference was attended by some members of the other group. The morning and afternoon sessions were attended by representatives of some 25 university, industrial, and government laboratories from Europe and the U. S. In the absence of Hugh M. Huffman, chairman of the previous three sessions of this conference, the meeting was presided over by Daniel R. Stull, of the Dow Chemical Company.

Herman L. Fink, of the U. S. Bureau of Mines, presented a report on thermochemical and calorimetric standards by the Subcommittee of the NRC Committee on Physical Chemistry. The report pointed out that by international agreement the absolute joule has been selected as the standard unit of energy. This unit may be transferred from the national standardizing laboratories to the investigator's laboratory by the use of appropriate electrical standards and in some cases by means of a standard substance which takes part in a chemical reaction. The report continued with recommendations bearing on the physical states and chemical changes involved in calorimetric measurements, and dealt more specifically with the problems associated with combustion calorimetry; specific heat of solids, liquids, and gases; and solution calorimetry, including heats of solution, heats of reaction, and heats of dilution.

In former meetings of this conference, three substances were chosen as standard materials for the comparison of calorimeters. Normal heptane (bp + 98.4° C, mp − 90.55° C) was selected as a liquid for the low temperature range, benzoic acid (mp + 122.36° C) as a solid substance for the same range, and synthetic sapphire for work at high temperatures. These samples have been prepared under the direction of Edward Wichers of the National Bureau of Standards, and the methods and precautions observed in their preparation were described to the conference by George T. Furukawa. They are now ready for issue, and are not regarded as part of the standard sample series of the bureau, but are reserved for the use of the conference and for related special purposes. Since the

initial purpose of these samples is the comparison of the values of specific heat measured in different calorimeters and by different methods, and in view of the elaborate purification and high purity of the samples, it was the recommendation of the conference that the samples not be squandered by use as a calibrating substance, but used for the purpose of comparison. Hence, the above samples will be issued without charge by the National Bureau of Standards to any reputable laboratory agreeing to report the results of their measurements to the bureau. Requests for these samples should be made to F. G. Brickwedde, National Bureau of Standards, Washington 25, D. C. It was suggested that the results of these measurements and their comparison would be of interest to the conference at some future meeting.

A discussion arose over the merits of a fractional melting technique vs. a fractional freeezing technique as a method of purification. It was brought out that when thermal equilibrium exists, these two methods become identical.

John G. Aston described plans for reestablishing the temperature scale of Pennsylvania State College. Since 1933 the temperature scale of this laboratory has been based on copper-constantan thermocouples which are now about worn out. The new scale will be based on eight platinum resistance thermometers, and will be compared with a helium gas thermometer from 10° to 90° K. In close cooperation with the National Bureau of Standards, improved apparatus, particularly manometry, has been constructed, which Dr. Aston feels will decrease the departure of his scale from the true thermodynamic temperature scale to about 0.03°.

H. L. Johnston, of Ohio State University, mentioned some high pressure PVT (pressure-volume-temperature) work in progress in his laboratory which will yield improved virial coefficients of helium, and decrease their uncertainty to perhaps one third. Dr. Brickwedde pointed out that increased certainty in these virial coefficients would depend upon the value of the gas constant R. Drs. Johnston and Brickwedde then developed the facts that the thermodynamic temperature scale (based on a perfect gas) could be defined in two different ways: (1) the difference in temperature between two thermal states (say steam and ice) can be assigned a value; and (2) a value can be assigned to a single thermal state (say the ice point). Thus, either way, the whole scale will be fixed. Dr. Brickwedde remarked that the International Union of Physics at its last meeting had recommended that the temperature of the ice point be selected once and for all time by the International Bureau of Weights and Measures.

Another project of the conference aimed at unification of the temperature scales of the various laboratories engaged in calorimetry was the construction of forty platinum resistance thermometers (platinum thimble type) of one lot of platinum wire by the Leeds & Northrup Company of Philadelphia. These forty thermometers have been purchased by various laboratories, and are being sent to the National Bureau of Standards for calibration. By special arrangement, the bureau will calibrate these thermometers down to 11° K. Harold J. Hoge described the methods used to compare these thermometers with NBS standard platinum resistance thermometers previously calibrated against a helium gas thermometer. Dr. Hoge mentioned that up to the present time, sixteen of these thermometers have been calibrated from 11° K, two are in the process of calibration, and six are awaiting calibration.

F. W. Schwab and E. Wichers (*J. Res. Nat. Bur. Stand.*, 1945, **34**, 333) have developed a Pyrex cell containing benzoic acid for use as a secondary fixed point in thermometry. Dr. Hoge reported that to date more than sixty of these had been issued, and are certified $\pm 0.003°$ C by the bureau. Experimental work is now in progress on new cells containing diphenyl oxide, tert-butyl alcohol, and normal heptane.

Dr. Hoge also described a special potentiometer in use by the bureau, and built by the Rubicon Instrument Company, of Philadelphia. This potentiometer will measure up to a total of 31 v with a precision of one part in ten thousand when measuring over one volt.

R. B. Scott described a new Simon type helium liquifier recently built at the National Bureau of Standards. It contains a stainless steel bomb of 1800-ml capacity surrounded by liquid hydrogen and in turn by liquid air.

J. G. Aston described a convenient helium liquifier recently built in his laboratory. The constructional features are such that the apparatus lends itself nicely to a variety of different experiments. At present it is being used to study the adsorption of gases on titanium dioxide. The equipment contains a Woods metal joint which is easily opened and closed vacuum tight.

E. F. Mueller, of the National Bureau of Standards, described two unsuccessful attempts to construct platinum resistance thermometers of 1.25-mil wire. He described two G2 Type Mueller bridges (constructed by Leeds & Northrup Company, of Philadelphia, for the bureau) containing resistors made of the new gold-chromium alloy which is reputed to have properties somewhat improved over manganin. He reported that a third such bridge has been built by the General Electric Company of Schenectady, New York.

New alloys are in prospect which may meet the stringent requirements set down by Mr. Mueller, as follows:

1. The wire shall have a coefficient from 20° to 30° C which does not exceed 1 ppm.
2. As the temperature of the coil goes up above 25° C, the resistance goes down.
3. The coil must be stable over a period of time.

In 1947 Mr. Mueller designed an improved bridge along the lines of the G2 type. Among the new features may be listed:

1. Range up to 400 ohms.
2. Lowest dial has steps of 0.00001 ohm.
3. Milliammeter improved so that by taking the resistance at two values of current one can extrapolate to the resistance at zero current.
4. Commutator also reverses the ratio arms.
5. Larger knobs on the dials.
6. Twelve positions on each dial.

I. Estermann reported on another project carried out by members of the conference. During the war, some of the specialty calorimetric materials were ordered in bulk, and resold to participating laboratories on a nonprofit basis. For example, some twelve or fifteen participants made up an order of some $2500 worth of monel and inconel tubing. If ordered individually, it would have cost at least twice this figure. In some cases, short pieces were shipped by mail from the Carnegie Institute stock, and much time was saved. In about six weeks or so, another order will be gotten together, and anyone interested should write to I. Estermann, Carnegie Institute of Technology, Pittsburgh.

Dr. Estermann emphasized the fact that in several cases errors in third law entropies have come from transitions which occur below the temperatures which can be reached by liquid nitrogen. Hence, extrapolation from liquid nitrogen temperatures to absolute zero involves this uncertainty. Dr. Estermann also proposed a rapid search with a calorimeter of say 1 to 2% accuracy to hunt for such transitions, and to survey a number of compounds to single out those profitable for further study.

Symposia on Conformal Mapping and the Monte Carlo Method[1]

J. H. Curtiss and E. F. Beckenbach

National Bureau of Standards, Washington, D. C.

Symposia on the Construction and Applications of Conformal Maps and on the Monte Carlo Method were held in Los Angeles at the Institute for Numerical Analysis of the National Bureau of Standards at the end of June. Between these two symposia, a two-day condensed course in automatic computation was given under the direction of Harry D. Huskey, head of the Machine Development Unit of the institute. The symposia and the condensed course formed an integrated series of lectures and discussions on topics pertinent to the work of the institute, which lasted for some ten days—from June 22 to July 1 inclusive. The combined registration for all the events, as recorded at the institute, totaled about 350 persons. The meetings were held in various buildings on the campus of the University of California at Los Angeles, where the Institute for Numerical Analysis is located.

The purposes of the Symposium on the Construction and Applications of Conformal Maps were to consider physical applications of conformal maps and their generalizations, and to study the construction of conformal maps with a view to determining the possible applicability of high speed electronic digital computing machines in this field. The symposium began on June 22 with a one-day course on programing for automatic computers given by the staff of the bureau's National Applied Mathematics Laboratories (of which the institute is one unit). This course was designed to acquaint those attending the later meetings of the symposium with the preparation of problems for automatic digital computing machines, and was especially arranged to appeal to mature mathematical analysts and applied mathematicians.

The morning of the second day was devoted to a general mathematical introduction in the form of addresses by Richard von Mises, of the Graduate School of Engineering of Harvard University, and Richard Courant, director of the Institute for Mathematics and Mechanics of New York University. J. H. Curtiss, of the National Bureau of Standards, was chairman of this meeting. Dr. von Mises gave a critical review of digital methods now available for constructing conformal maps. He strongly stressed one point which was of considerable interest to the persons in the audience concerned with machine development: In his opinion what is now really needed more than anything else in the field of high speed automatic computation is a machine which will solve very large systems of linear algebraic equations. He suggested in this connection that the speed of a proposed digital computing system should be measured in terms of the number of algebraic equations it can solve in a given length of time, rather than by its speed of multiplication. Dr. Courant's lecture was devoted to the conformal mapping of multiply connected regions, particularly as illustrated by flow patterns, and he touched upon the use of various analogue devices such as electrolytic tanks to calculate such maps.

The afternoon session, with D. V. Widder, of Harvard University, as chairman, was devoted to papers on physical and industrial applications of conformal mapping by G. Szegö, H. Poritsky, G. Stein, Ernst Weber, and I. S. Sokolnikoff. J. L. Barnes, of the University of California, Los Angeles, and North American Aviation, Inc., was chairman of the next morning session, which was concerned with fluid dynamics. Speakers were Alexander Weinstein, I. E. Garrick, Alexander Ostrowski, S. E. Warschawski, Andrew Vazsonyi, and E. P. Cooper.

Discussions of the theory of conformal maps occupied the next afternoon session. W. T. Martin, of Massachusetts Institute of Technology, was chairman and papers were presented by A. C. Schaeffer, D. C. Spencer, Stefan Bergman, Menahem Schiffer, Zeev Nehari, and P. R. Garabedian.

The general morning session with which the last day of the conformal mapping symposium opened was presided over by J. W. Green, of the University of California, Los Angeles. Papers were contributed by L. V. Ahlfors, L. Bers, P. C. Rosenbloom, G. Szegö, R. Isaacs, and M. Shiffman.

H. F. Bohnenblust, of California Institute of Technology, was chairman of the final afternoon session, devoted to numerical methods and additional notes. Speakers were Sir Richard Southwell, H. D. Huskey, D. M. Young, O. Laporte, H. Lewy, and L. H. Swinford.

The symposium was arranged by a committee of the Institute for Numerical Analysis under the chairmanship of Edwin F. Beckenbach. The role played by the Office of Naval Research in the proceedings was a significant one: a considerable number of the papers (e.g. those of Pólya and Szegö, Spencer and Schaeffer, Garabedian) arose from projects sponsored by ONR, and in fact the

[1] Proceedings of both symposia are being published by the National Bureau of Standards.

entire research group of the institute itself is also supported by ONR. Several interesting conclusions could be drawn from the symposium. In the first place, it seemed clear that there is a continuing interest in conformal mapping on the part of scientists working in the applications of mathematics, especially in electrical engineering and fluid dynamics. In the second place, it became evident that there was a need for a much more extensive catalog of conformal maps (given both analytically and in tabular form) than now exists. Finally it seemed apparent that digital techniques adaptable for automatic computing machinery are at present receiving little attention by those working in the field of conformal mapping, and extensive comparative studies of the relative usefulness of known methods and the newer probabilistic methods are now very much needed.

The Symposium on the Monte Carlo Method was arranged and sponsored jointly by the RAND Corporation of Santa Monica and the Institute for Numerical Analysis, with the cooperation of the Oak Ridge National Laboratory. Because the symposium dealt for the first time with an interesting branch of applied mathematics on which work hitherto has largely been carried on under a cloak of classification, the symposium attracted a considerable amount of attention, particularly from personnel of the laboratories of the Atomic Energy Commission.

The Monte Carlo Method can be described quite generally as the representation of a physical or mathematical system by a sampling operation satisfying the same probability laws as the system itself. Thus for example, the numerical integration of partial differential equations of a certain type can be accomplished by building up a large sample of trials of certain stochastic processes whose probability functions asymptotically satisfy the partial differential equations. In certain physical situations formerly represented by such equations, the physicist may prefer to place primary emphasis on the stochastic processes and the associated sampling operations, which he will then regard as new models to be used in place of the continuous models of classical applied mathematics.

The over-all plan of the Monte Carlo Symposium was evolved in conversations held by the committee on arrangements with J. von Neumann, of the Institute for Advanced Study.

An essential part of the plan was that a gallery of distinguished mathematical statisticians and experts in the analytic theory of probabilities would be present in the audience during the first two days, and that on the afternoon of the last day they would participate in a round table discussion at which the proceedings of the earlier sessions would be examined from the mathematician's and statistician's viewpoint.

After the introductory session on the morning of June 29, at which S. Ulam and J. von Neumann discussed the history of the Monte Carlo Method and outlined the areas in which it is being applied, some twelve papers covering current applications were given by the following scientists: Robert R. Wilson, B. I. Spinrad (a joint paper with G. H. Goertzel), A. S. Householder, Wendell DeMarcus (a joint paper with Lewis Nelson), Ugo Fano, Gilbert W. King, Maria Mayer, Preston Hammer, B. A. Shoor (a joint paper with Lewis Nelson, Wendell DeMarcus, and Robert L. Echols), and Herman Kahn (a joint paper with T. E. Harris). A paper by Lt. Williston Shor, U.S. N., was read by title. The sessions were under the chairmanship of J. von Neumann and Frank C. Hoyt.

A session on random digits was held on the afternoon of June 30 under the chairmanship of Jerzy Neyman, University of California. Three shorter papers were given first on the generation and testing of random digits by George W. Brown, Nicholas Metropolis, and George E. Forsythe. Dr. von Neumann then gave an interesting general discussion of the philosophy of random digits and of various possible techniques that could be used in generating them. One of the points he made was that any number used during the course of a computation in automatic digital computing machines ought to be the product of a reproducible routine, and from this point of view mathematically generated "pseudo-random" numbers and digits are to be preferred to random digits created by some sort of physical or mathematical "truly random" sampling process which takes place within the machine.

Both of the last day's sessions were under the chairmanship of John W. Tukey, of Princeton University. In the morning a mathematical session on the connection between stochastic processes and differential equations was held. William Feller first gave an informal general survey of the field. He was followed by J. L. Doob, who presented some recent results on stochastic differential equations, and then Mark Kac discussed certain results relating to the distributions of cumulative sums of random variable and differential equations. At the round table discussion in the afternoon of the last day it was emphasized that the method of sampling had long been used in the statistical field to solve difficult problems in distribution theory.

The symposium indicated that there are many interesting possibilities in the Monte Carlo method, particularly if it is used in connection with automatic digital computing machinery. The mathematicians of the Institute for Numerical Analysis concluded that the method is at present largely being employed by physicists as a rough tool of applied research to obtain results which can later be checked against experiment, and more attention now needs to be given by mathematicians to the theoretical aspects of the model considered in the light of the modern classical theory of stochastic processes. They also concluded that the use of the Monte Carlo Method as a technique for solving strictly mathematical problems, such as partial and ordinary differential equations, is in its infancy and much experimental numerical work as well as theoretical work must be done before the advantages of the method for a wide area of problems over the older deterministic methods of solution are established. The symposium also brought out once again that the modern classical analytic theory of probabilities is still a closed book to many mathematicians and physicists, and that there is urgent need for competent and well-organized exposition in the field.

International Conference on Instruments and Measurements

Edy Velander

Swedish Academy of Engineering Sciences, Stockholm

Three hundred fifty scientists and engineers from 16 different countries met September 21 at Stockholm, Sweden to take part in an international conference on instruments and measurements under the sponsorship of the Royal Swedish Academy of Engineering Sciences and the Association of Technical Physicists. Unesco was represented by an observer, R. Naidu. For four days papers were given and discussions were held in four parallel divisions: physical methods for the study of chemical structure, such as spectroscopy and X-rays; mechanical measurements; industrial control; and metrology.

The conference was opened by Edy Velander, of the Swedish Academy of Engineering Sciences, and the opening lecture was made by W. E. Wildhack, of the U. S. National Bureau of Standards, who characterized instrumentation as the common denominator of the sciences. Instrumentation, he said, is the connecting horizontal link between the vertical divisions of science—chemistry, physics, biology, and the others. Mr. Wildhack also brought greetings from the Fourth National Instrument Conference and Exhibit in St. Louis, Missouri, sponsored by the Instrument Society of America.

In the spectroscopy division, A. C. Menzies, of Hilger and Watts, Ltd., London, talked on progress in Great Britain in infrared and Raman spectroscopy. Dr. Menzies described a new source for Raman spectroscopy which permits spectra suitable for qualitative work to be obtained with exposures measured in seconds, and spectra suitable for quantitative work in about a minute. Edy Velander

(Continued on page 383)

Photographs, 1, 3, and 5, opposite page — booths at the International Instruments and Measurement Exhibit, Stockholm (courtesy of Dagens Bild, Stockholm). Photographs 2 and 4—Raydist master recording station and continuous wave transmitter, on display at the National Instrument Exhibit at St. Louis. Manufactured by the Hastings Instrument Company, Hampton, Virginia, for the Bureau of Ordnance, U. S. Navy, the Raydist automatically spots a vessel or any other object sending out radio waves in a given area. It measures distances up to 200 miles, unimpeded by mountains or tall buildings that intervene. Photograph 6, by Eugene Taylor, shows smoke density recorder displayed by the Bailey Meter Company, Cleveland, at the St. Louis Exhibit.

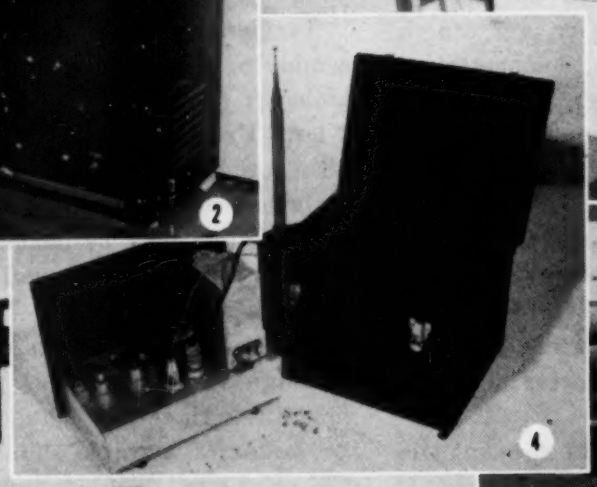
Sketches below, made at the Stockholm conference, are by Niles Melander.

ZEISS SVENSKA AKTIEBOLAG
ELEKTRONIKBOLAGET
RCA
GEC

1

2

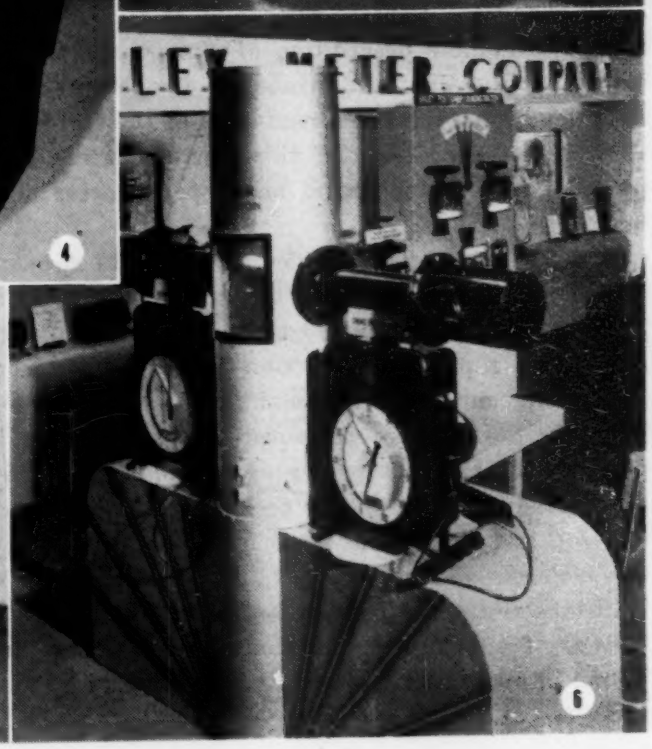
3



4

HUGO TILLQUIST

5



6

Summaries of Selected Papers Presented at the 1949 National Instrument Conference

A Mass Spectrometer for Isotope Ratio Determinations

H. F. Wiley

Consolidated Engineering Corporation
Pasadena, California

Research workers in the fields of chemistry and biochemistry have today an attractive opportunity to use the stable isotopes of a number of common elements for tracer experiments, largely as a result of two recent developments. First, compounds enriched in the stable rare isotopes have become generally available at reasonable cost. Second, a mass spectrometer designed specifically for isotope ratio measurements now can be purchased as a complete unit.

The advantages of using stable rare isotopes for tracer experiments, as compared to using radioisotopes, are that nitrogen and oxygen have suitable stable but no suitable radioactive isotopes, and that deuterium, the stable isotope of hydrogen, may be obtained in nearly pure form. The main disadvantages are that the assay equipment is much more complex and expensive, and that the rare stable isotopes occur in nature in relatively large abundances, thus limiting their ultimate dilution when they are used as tracers. Their occurrence in nature makes possible, however, the interesting work in the field of geology reported by H. C. Urey, A. O. Nier, and others.

Following the work of J. J. Thompson, demonstrating the isotopic nature of neon, A. J. Dempster, F. W. Aston, and others designed and used mass spectrographs for the accurate determination of the masses of the isotopes of many elements. Several years ago A. O. Nier published a fairly complete description of a mass spectrometer in use at the University of Minnesota for the precise determination of the relative abundances of the stable isotopes (*1*). The basic design of this instrument has been employed in the isotope ratio mass spectrometer described here.

The fundamental principles of the mass spectrometer are illustrated in Fig. 1. The sample of gas, at an absolute pressure of about 30 mm Hg, is continuously bled through a capillary restriction into an "ion source." In the ion source, which is maintained at greatly reduced pressure, the gas molecules are bombarded by a stream of electrons emitted by a tungsten filament. The electrons have sufficient energy so that on the collision of an electron and a molecule there is a high probability that the molecule will be ionized. A certain portion of the collisions result in dissociation and the ionization of one or more fragments of the molecule. The ions are projected into the analyzer tube at high velocity by means of an electrostatic field in the source. In the analyzer tube the ions pass through the field of a 60° sector magnet, which causes the ions of different masses to follow different paths. The intensities of the accelerating and magnetic fields are adjusted to focus all ions of one particular mass on a collector, and the current to this collector is amplified and measured.

Most mass spectrometers have only a single ion collector. A comparison of the intensities of the two different ion beams requires the focusing and measuring of each beam in turn. In the isotope ratio instrument, however, there are two collectors, arranged so that all ions of one specific mass strike one collector at the same time that all ions of another specific mass strike the other collector. The currents to each of the two are amplified and the ratio of their magnitudes read directly.

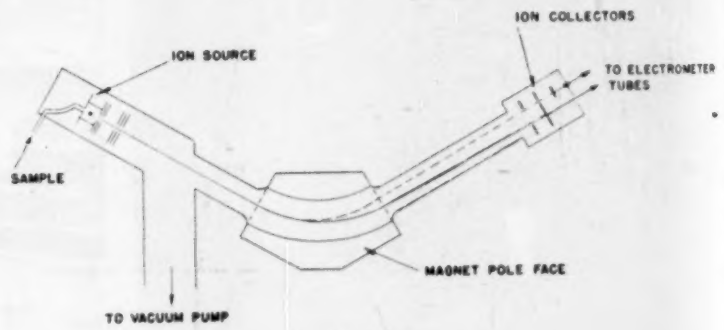


FIG. 1.

The ion source, analyzer tube, and dual collector assembly of the Consolidated-Nier isotope ratio mass spectrometer (*2*) follow closely the construction described by Nier. Except for small glass insulators, these parts are all metal, principally nichrome, inconel, and nonmagnetic stainless steel. The analyzer tube is covered by a heater winding and may be baked out at a controlled temperature to reduce background gases after exposure to the atmosphere.

A permanent magnet is used in place of the usual electromagnet and associated power supply. The magnetic field strength can be changed over a range of four to one by means of movable shunts which divert the flux from the main gap. The position of the shunts is adjusted by rotating a small hand wheel.

The high vacuum system for the analyzer tube consists of a cold trap, a water-cooled mercury diffusion pump, a ballast volume, a mechanical backing pump, and a vacuum gage. Dry ice or liquid nitrogen is used as the coolant in the trap.

The electronic circuits consist of a high voltage power supply for the ion-accelerating potentials, an electron emission regulator, and the ion current amplifiers and their power supply. The high voltage power supply provides a voltage of 2000 v, regulated to about 0.1%. The

emission regulator maintains the electron ionizing current at a constant value by controlling the temperature of the tungsten filament. Two identical ion current amplifiers are used, each amplifying the current to one of the two collectors. The amplifiers employ a unity gain circuit in order to meet the severe requirements with respect to dynamic range, sensitivity, and stability. The first stage, or preamplifier, of each amplifier is mounted close to the collector assembly and its components are carefully matched to the other to reduce the drift of the amplifiers with respect to each other.

The few controls and switches are mounted within easy reach of the operator. The most important of these are the decade dials and null indicating meter used in measuring the isotope ratio.

The resolution of the isotope ratio mass spectrometer is adequate for precise ratio measurements up to about mass 70. In the case of CO_2 the contribution of mass-44 ions to the mass-45 ion beam is less than 0.04% of the mass-44 ion beam intensity.

The dual collectors cannot be used for the simultaneous collection of hydrogen and deuterium ions because of the greater spatial separation of the two ion beams at the points of focus. Provision is made, however, for conveniently comparing their intensities by using a reference voltage as a standard.

TABLE 1

REPRODUCIBILITY OF SUCCESSIVE ISOTOPE-RATIO DETERMINATIONS

Reading No.	N_2 Mass 29 / Mass 28	CO_2 Mass 45 / Mass 44	H_2 Mass 3 / Mass 2
1	.007569	.011596	.000395
2	.007563	.011598	.000393
3	.007570	.011594	.000396
4	.007564	.011599	.000398
5	.007567	.011593	.000395
6	.007564	.011594	.000397
7	.007565	.011596	.000396
8	.007567	.011597	.000399
Mean	.007566	.011594	.000396
S. D.	.0000025	.000003	.000002

Only gas samples can be introduced into the instrument, so the products of an experiment must be converted to CO_2, N_2, O_2, or $H_2 - D_2$, depending on the tracer used. The sample is bled into the evacuated introduction system from a suitable container through a system of stopcocks, and a Toeppler pump is provided for adjusting the sample pressure. Gas samples as small as 0.1 ml S.T.P. can be handled. To achieve maximum precision all related samples are compared to a standard sample, and this standard is run frequently in order to overcome the effects of long term drifts. The excess of rare isotope is computed with reference to the standard.

It is of great practical interest to know the maximum dilution which an enriched material can undergo and still be detected. This ultimate dilution can be computed from the enrichment of the tracer material and the minimum detectable excess of the rare isotope over its natural abundance in the dilutant. While the minimum detectable excess may be affected by natural variations of the normal material, it is the precision in measuring a change of isotope ratio at the normal abundance level which is considered here. With the mass spectrometer described, the ratio is read to six figures and is significant to about .000005, as illustrated in Table 1. Each column of this table represents eight successive measurements made within a short period of time on a single sample of the gas indicated.

With precision comparable to that shown in Table 1, 30 atom % enriched hydrogen, nitrogen, or carbon may be diluted to 1 part in 100,000 in normal material. For the great majority of applications, this precision is highly satisfactory; thus the isotope ratio mass spectrometer is a tool of outstanding value in the numerous scientific investigations involving stable isotopes.

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The Photographic Plate as an Instrument in Nuclear Research Autoradiography and Radiation Monitoring

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The photographic plate has become in recent years a very valuable tool for measurement of radiation from radioactive materials. Such radiations include charged particles of all types—electrons, protons, alpha particles, and ionized atoms, as well as electromagnetic radiation such as X-rays and gamma rays. Extensive applications of the photographic plate have been made in the fields of nuclear physics, autoradiography, and in radiation monitoring.

Nuclear physics. In 1945, following the tremendous expansion in nuclear physics during the war period, and the development of higher energy accelerators, physicists began to look seriously to the photographic plate as a means of registering the paths of high energy charged particles. For this purpose, the photographic plate resembles closely in action that of the Wilson cloud chamber. However, the silver bromide emulsion with its high stopping power (about 2,000 that of air), continuous sensitivity, and simplicity, gives it distinct advantages not possessed by the cloud chamber.

The Ilford Company in England pioneered in the field of producing the modern type nuclear emulsion and in 1945 produced a series of plates that far surpassed in sensitivity plates previously made. Subsequently, the Eastman Kodak Company in America, together with their British affiliate, Kodak Limited, started a program of

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research which resulted in a series of plates that paralleled in quality and exceeded in sensitivity any previous plates. Plates are now commercially available that will record any type of charged particle, including electrons at the minimum ionization energy, with clear tracks, and low background fog.

Nuclear track plates differ markedly from the ordinary optical type emulsions, being distinguished by a high silver bromide-to-gelatin ratio, by extremely small and uniform grain size, and very great thickness. Whereas the optical type emulsion has a silver bromide-to-gelatin ratio of about 50: 50 and a thickness of 10 μ, the nuclear track emulsion has a silver bromide-to-gelatin ratio of 80: 20 and a thickness between 25 and 300 μ.

A charged particle on passage through a material medium loses energy at a definite rate per unit of distance, depending upon its charge and velocity and upon the number of electrons per cm^3 of the stopping material. The main portion of this energy loss goes into production of ions through the interaction of the particles with the electrons of the stopping atoms. The energy loss varies directly with the square of the charge on the particle and inversely as the square of its velocity. However, at velocities approaching that of light, the inverse v^2 relationship becomes constant and relativistic effects enter to cause the energy loss curve to pass through a minimum value and rise slightly at higher energies.

Photographic action of charged particles is closely linked with the energy loss rate curve described above and the sensitivity of an emulsion can be specified in terms of the highest energy particle that can be recorded. Low velocity particles have strong photographic action and high velocity particles have weak photographic action. Plates are now available that record particles at energies corresponding to the minimum of the energy loss rate curve and will thus pick up a background from cosmic ray electrons. The useful life of such plates is limited in this way to about three weeks, there being no practical means of shielding.

The factors of range in the emulsion, grain spacing in the track, and the scattering of particles passing through the emulsion are important to the research worker doing quantitative work in nuclear track photography. By a combination of these attributes, it is possible to draw conclusions about the mass, charge, and energy of the particles under observation.

Autoradiography. A very important application of the photographic plate in recent years has been in the field of autoradiography. This consists in the technique of locating and measuring the distribution of radioactive elements by means of photographic registration of the emanations from these elements. This means has been used for years in the study of naturally radioactive constituents of minerals such as radium and thorium. Limitation of radioactive elements to the few naturally occurring ones correspondingly restricted the field of autoradiography. With the advent of atomic energy and the atomic pile, it has now become possible to produce radioactive isotopes of practically all the elements of the periodic table in considerable quantities. The use of active isotopes in conjunction with the photographic plate has placed an extremely valuable tool in the hands of the chemist, metallurgist, biologist, and petrographer, whereby chemical elements can be traced in various substances, reactions, and processes peculiar to each of these fields of work.

The technique of autoradiography consists essentially in placing a photographic emulsion in contact with a given test sample of material and registering a self-portrait of that surface by means of "tagged" tracer atoms in or near the surface. The picture may consist of a series of smoothed-over density values, as obtained in an ordinary picture, the contour map of the densities indicating the intensity of radiation. If, however, the radioactive atoms are very sparse it may become necessary to make a microscopic survey of the developed emulsion to determine the concentration of radioactive atoms from track counts. This method, though tedious, permits almost unbelievable sensitivity, it being possible to locate concentrations of the order of 10^4 atoms with isotopes having a few days' half-life. Another feature of track autoradiography is that it permits, under favorable circumstances, the exact location of the emitting atom through location of the start of the track. Measurements have been published showing the location of active atoms within a few microns.

Radiation monitoring. Photographic plates are being used extensively now as a monitoring instrument for the detection of health hazards. A small piece of photographic film in the form of a dental packet can be worn on the person of a radiation worker and used as a continuous integrating device for measuring either particle or gamma radiation. In monitoring for radiation, it is necessary to measure X-rays and hard gamma rays, since these are very penetrating and are frequently hazardous.

The fastest X-ray emulsions will register as little as 0.05 roentgen and cover a range to about 2.0. Emulsions are available covering the range of exposures from this low limit up to 5,000 r.

The materials used in a badge usually include a high speed film covering the range 0.05 r to 2 r and a second film covering the range 1 r to 10 r. In addition, a third film may be included to monitor for neutrons. The manner of operation is as follows: A piece of Cd 1 mm thick is placed over part of the badge. The Cd will stop slow neutrons, beta particles, and soft X-rays. Therefore, the unshielded films will register beta radiation and soft X-rays. Behind the Cd shield, the films register the hard X-rays and gamma rays. The bottom film is a nuclear track emulsion that will register proton tracks. Slow neutrons can pass through the films on the side unshielded by Cd and give use to the nuclear reaction $N^{14}(n, p)C^{14}$ by interaction with the N atoms of the emulsion. The fast neutrons penetrate the Cd shield and collide with hydrogen nuclei in the emulsion to give knock-on protons. It turns out that tolerance levels of fast and slow neutrons give convenient track counts in two weeks' exposure.

Industrial Radar for Hurricane Tracking

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An explanation seems in order as to why an industrial corporation manufacturing chemicals has apparently invaded the province of the U. S. Weather Bureau in tracking tropical storms. The facts are that the program is not in competition with the Weather Bureau, but in cooperation with it; and it was undertaken in order to facilitate chemical manufacture. A hurricane need come no closer than a hundred miles to cause thousands of dollars' loss to the Dow Plants. The vulnerability of the site on the Texas Gulf Coast and the nature of some of its operations require that plant shutdown be started about twelve hours before the occurrence of hurricane winds.

A hurricane is an area disturbance consisting of circular winds about a calm center or eye. Apparently most such storms originate in the tropics, but they travel far and may strike coastal areas anywhere in the Tropical or Temperate Zones. Those in the Northern Hemisphere always rotate counterclockwise, while those in the Southern Hemisphere rotate clockwise as viewed from above. Hurricanes are usually dangerous over a diameter of 100 miles or more, with the worst winds near the center. The calm area at the center may be several miles in diameter, and barometric pressure may be as low as 27 in. In addition to the very severe circular winds, which may exceed 100 mph, the whole disturbance moves as though it were a giant top spinning and sliding at the same time. This "forward" or sliding motion, which it is sought to follow or predict, usually ranges from 4 to 15 mph. However, the storm may stay in one spot for half a day or double back on its past track.

A single storm may have a life as long as two weeks, during which it traverses thousands of miles of ocean. Once the cycle is started, energy is poured into the storm continuously in the form of warm moist air. This causes heavy rains as it spirals in toward the center and the resulting pressure drop provides impetus for continued winds and more rain. The storm usually dissipates soon after hitting land areas, but these hurricanes cause much damage and loss of life on the Gulf and Atlantic coasts. They are invariably accompanied by extremely high tides and usually by torrential rains.

The inhabitants of inland areas may have difficulty in comprehending the destruction of a hurricane, considering that the 125-mile-an-hour winds are only a fraction as great as those of a Great Plains twister. The explanation is in the large area covered and the high water. Tides of 16 ft have been experienced along the Gulf Coast, and 40-ft storm tides are not unusual in some areas. Add to this the fact that many coastal communities are 4–8 ft above sea level and it becomes apparent that cyclone cellars are of no value.

What property of a hurricane allows it to be detected by means of radar? During the war it was discovered that aircraft could hide in heavy rainstorms and avoid detection by some types of radar because the rain gave a radar indication of the same type as an airplane, but over a wide area. The indication was not changed by the presence of an aircraft in the rain area. Later it was found that hurricanes presented a distinct picture on these radar sets because of the rain which almost invariably accompanies them. Fig. 1 shows a typical picture of the radar presentation of a hurricane on a plan position indicator. The picture is equivalent to a map or plan view of the area with the radar located at the convergence of the radial lines. These lines and the range circles form a polar coordinate reference system used to locate targets accurately with respect to the radar.

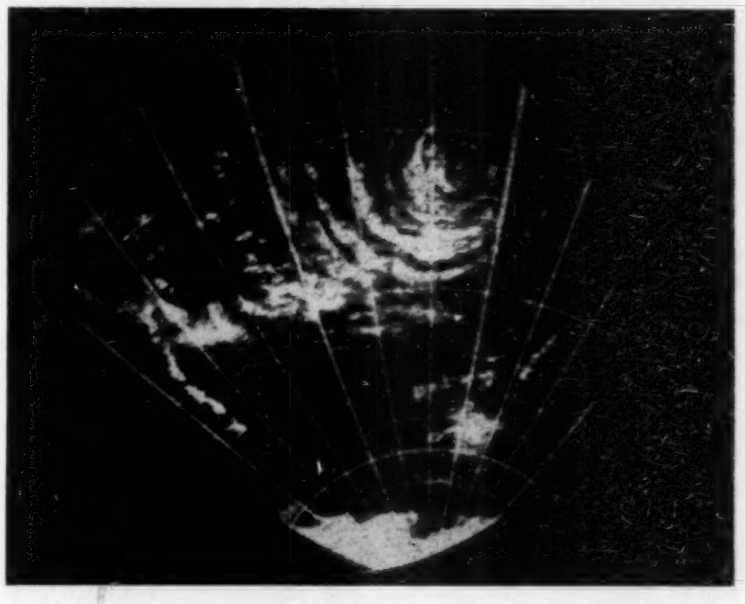


FIG. 1.

The irregular white areas represent radar reflections fom the bands of heavy rains. Radar returns of this type have been found to result from hurricanes in all parts of the world, and have never been observed from any other cause. The picture shown was made from the 'scope of a 10-cm Army radar during the 1945 hurricane which went up the Florida peninsula.

The timing device of a pulsed radar set controls the entire set—transmitter, receiver, and the presentation device. Powerful pulses of radio energy are generated by the transmitter and radiated in a highly directional beam. The receiver antenna and the receiver pick up the returned echo (if any) and send the notice of arrival to the presentation device, which measures the time required for the signal to echo from any target and gives a visual indication of this time. Usually the size and intensity of the echo and its azimuth bearing from the radar are also shown.

A single such pulse will give an indication of all the echo-producing objects in the path of the radio beam. However, since it may be desired to sweep the antenna rapidly through the complete 360° of rotation and scan the complete area covered by the radar, provisions must be made to send out rapidly recurring pulses. Thus the timer is designed to wait only the minimum time required for the reception of an echo from the maximum expected range before repeating the cycle. In the event the antenna is not rotated, recurring echo pulses are in-

dicated in the same position on the indicator and are integrated by the persistence of the phosphor on the cathode ray tube to give a more distinct indication.

Practical radar sets usually have numerous additional blocks which perform auxiliary functions. Most sets have only one antenna, which functions alternately for the transmitter and the receiver through the use of an automatic switch. Power servo systems permit the operator to point the antenna in any desired direction by fingertip controls. Other devices may provide the automatic frequency control.

Radar for general use or search usually is equipped with a type of presentation known as the Plan Position Indicator, or PPI. In this unit, time is measured by the radial distance which a spot moves from the center of the cathode ray tube. Direction in which the spot moves is made to coincide with the direction in which the antenna is pointing. The spot starts from the center at the time the radio wave is sent out, and moves from the center outward at constant speed. Reception of an echo is made to brighten the spot momentarily. Since travel time is proportional to the distance to the echo-producing object, and time also is proportional to the radial distance the spot has moved on the indicator, this gives a bright spot for each echo-producing object in its map or plan aspect with reference to the radar set. Distance and angles may be scaled directly on this presentation.

The factors affecting radio propagation and the question of what causes a radio reflection or echo have been studied in great detail in connection with the wartime radar program. In general, any conductor of electricity or any insulator with properties greatly different from the atmosphere may cause a radio reflection. The reflection is usually diffuse, comparable to light reflected from a rough surface. To produce a strong echo, the object must be of a size comparable to or larger than a half wavelength of the radio wave. However, much smaller objects, such as drops of water, cause some reflection; and if there are enough of these objects in a given area, an echo will be received. Calculations show that the energy returned from a drop of water varies as the sixth power of the ratio of drop diameter to wavelength (*2*)

Practically, this means that 3000-megacycle or 10-cm radar sets will "see" rain, while 100- or 500-megacycle sets will not. Radar operating on 10,000 megacycles or 3 cm will indicate the presence of light rain or fog. Water drops of a minimum diameter of about 1.2 mm are indicated by 10-cm radar. Another point which should be emphasized is that an object need not be opaque to radio waves in order to produce an echo. An object may produce a radio echo and still transmit a large percentage of the signal. At times as many as three rainstorms in a row radially from a radar have been seen on the radar 'scope.

Radio energy of wavelengths commonly used in radar work travels essentially in straight lines, just as light does, and diminishes as the square of the distance from the source. Under normal atmospheric conditions there is a slight bending in the vertical plane which extends the radar horizon slightly beyond the optical horizon. To be "seen" by a radar set with its antenna at 25-ft elevations, an object at a range of 100 miles must have an elevation of about 4,000 ft, while at 300 miles an object must be about 40,000 ft high.[1] Thus, it is seen that there is a definite limit to the range that may be attained, even though a very large amount of power is used. Meterologists are in general agreement that the central core of a hurricane may rise to 50,000 ft but the maximum height at which water drops are present is probably somewhat less. Because of these considerations, it appears that no radar of present design located on the ground will be able to detect a hurricane at ranges much in excess of 300 miles. Occasionally radar targets are detected at ranges far beyond the optical horizon. This is caused by anomalous atmospheric conditions, creating a duct or layer through which radio waves are led around the earth's curvature. Unfortunately this phenomenon cannot be relied upon to extend radar coverage.

When it was decided to install a radar set for the purpose of tracking storms, the question of the most suitable type arose. The Weather Bureau recommended the SCR-584 or 784, since these sets are designed for about 3000 megacycles (10 cm) and have adequate power. A trailer-mounted SCR-784 was purchased and certain necessary modifications were made with the assistance of Weather Bureau personnel. The installation was made under terms of an agreement whereby all data obtained with the radar would be sent directly to the Weather Bureau and would be released to the public only through that agency. The set was located about two miles from the open Gulf on land about 18 ft above sea level, with a clear view seaward.

The SCR-784 has a very short pulse width or length of time during which energy is transmitted, and relatively short design range. This does not imply a lack of power, but rather a short listening period between transmitted pulses. The peak power of the set during the 0.8-microsecond transmitted pulse is 250 kw, or five times that of the most powerful commercial broadcast station. Modification of the set for the weather work began with a slowing of the pulse repetition frequency to give more listening time between transmitted pulses. Additional multivibrator stages were added to the timing circuits to give a frequency of 188 pulses per sec, which permits reception of echoes from objects 300 miles distant. Then the presentation unit was modified to cause the cathode ray spot to sweep more slowly, corresponding to the time required to receive echoes from the longer range. Multiple ranges of 100, 200, and 300 miles were provided, with a selector switch to choose among them.

This completed the necessary modifications, but several others were made in the interest of improved efficiency. A larger parabolic antenna reflector was installed in order to focus the radio waves into a sharper beam and thus give a higher concentration of energy and improved ability to resolve contiguous targets into separate pictures rather than merging them into a solid pattern.

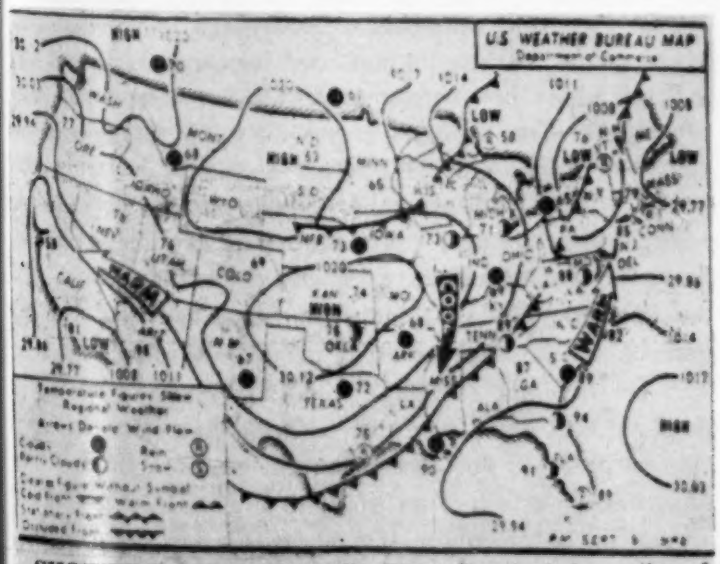
The slowing of the pulse repetition frequency previ-

[1] $R = 1.43\ (\sqrt{H_1} + \sqrt{H_2})$ Where R is range in miles and H_1 and H_2 are heights of radar and target in feet.

FIG. 2.

ously mentioned resulted in a reduction in the average energy transmitted by the station, since each pulse contains a definite energy and the number per second was reduced. In order to increase this average energy output, the pulse width was increased from the original 0.8 microsecond to 1.6 microsecond. In general, average power is unimportant so long as peak power is maintained, but a pulse of longer duration improves the signal from a diffuse object or one with depth, such as a rainstorm. This greater pulse width gives poorer resolution in range, but it is still more than adequate. The angular resolution of the modified equipment is of the order of two degrees, which means that at a range of 100 miles isolated objects less than four miles apart will have their echoes merged. This difference between angular and range resolution causes point targets to produce elongated pictures with the long axis tangent to range circles.

Other modifications included installation of a new preamplifier and a larger PPI tube. Camera equipment was arranged to permit rapid photographing of the screen with convenient means for identifying each picture as to date and hour. An automatic camera was also provided, to take a picture every minute. When projected as a movie film, the record of this camera should be very interesting.



SHOWERS OVER TEXAS—East Coast states enjoyed fair and warm weather. Showers and thunderstorms were reported from the St. Lawrence valley southwestward to extreme Southern Texas. Most of the Western states had a fair, mild day Thursday.

FIG. 3.

After the equipment was installed and modified, many observations were made to test the range and accuracy. Thunderstorms and isolated rains were observed and telephone calls were placed to verify the actual weather at the points where rain was indicated. Agreement was surprisingly good. Some cases of disagreement were apparently caused by rain in the upper atmosphere which evaporated before striking the ground. Results were consistent enough to show that rain will always be indicated. Many storms have been observed at ranges greater than 200 miles, at least one at 240 miles being verified. Echoes from 280 miles have been observed. Several times the radar screen has presented a picture of a line squall that agreed very closely with a front indicated on the official weather maps. Figs. 2 and 3 indicate one case of this type. Geographical features were dubbed in to orient the 'scope photograph better. This picture also illustrates a case of the radio waves' penetrating 80 miles of solid rain and still retaining power to produce an echo from rain 100 miles distant.

A program was set up for daily observations during the hurricane season—from the middle of June to the first of November. In the event that a tropical storm is known to be approaching, the equipment is manned continuously. A weather consultant is on hand to interpret the results and direct the experimental program. Experience during the war indicates that considerable information about a hurricane may be revealed by one observation on the radar screen. The center or eye of the storm is usually well defined as a clear area completely or partially surrounded by heavy rain. Even before the main part of the storm comes within range, the squall line associated with it may provide some information. These squalls may be from 40 to 100 miles from the center and they are thought to run at right angles to the line of progress of the storm. It is also generally acknowledged that rains are heaviest in the right front quadrant of the moving storm—this is based on storms in the Northern Hemisphere, which always have counterclockwise rotation as viewed from above. In a storm moving radially, that is, approaching the radar, the movement should be apparent from observations taken 15 min apart. This contemplates a speed of four mph and a range resolution of the radar of one mile.

As an experimental program, efforts will be made to obtain a vertical profile of the hurricane core by taking successive photographs as the angle of antenna elevation is increased. If this is successful at all, it will probably be at rather short ranges, since the angular resolution is hardly adequate for this.

Fortunately, the hurricane data obtained thus far with this equipment has been of a negative nature. That is, the first hurricane season and a portion of the second have elapsed with no hurricanes having presented themselves for observation. This does not dampen enthusiasm

for the program in any way, the range and reliability of the equipment having been proved on rainstorms. It must be acknowledged that the hurricane which struck New Orleans on September 3, 1948, passed within 300 miles of the radar. No indication of a hurricane or even of rain was obtained during its course. However, this particular disturbance barely qualified as a hurricane, the highest wind velocity being 70 mph. Undoubtedly it did not reach the altitude required for radar observation at this extreme range.

Cosmic Ray Instrumentation

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Cosmic ray work is a subject rich in examples of advances in instrumentation leading to great discoveries in pure science. Cosmic ray research started, in fact, as instrument research, as the investigation of the leakage of electricity through the air in electrometers. Coulomb (1785) can be considered its founder. His career exemplifies the mutually beneficial interaction between basic research and instrument development. He first determined the law of torsional elasticity, the way in which the elastic constant depends on the radius and length of the cylinder. He then used this knowledge in the construction of a torsion balance of unheard of sensitivity. With this instrument, which could measure forces down to 0.005 dynes, he discovered the inverse-square law of force between electric charges. He then made a more sensitive torsion balance, readable to 0.001 dyne, with which he was able to prove, long before Faraday's ice pail, that there is no electricity on the inner surface of a conductor in equilibrium. Like everyone who has experimented with static electricity, Coulomb observed the apparently inexorable leakage of charge. He, however, studied it quantitatively, and resolved it into leakage along the supports and a leakage through the air. He planned a careful study of the dependence of the rate of leakage on the nature of the gas, its density, and its humidity, but had to postpone the project for lack of "instruments to measure exactly the purity of each gas and its humidity." Had Coulomb carried out this program, he would have been well into the physics of ionization chambers.

More than a hundred years later, in 1900, it was found that the conductivity of the air is due to continual ionization, and C. T. R. Wilson, in 1901, published the bold speculation that this ionization is due at least partly to an extremely penetrating radiation from outside the earth. In 1912-13, Hess and Kolhoerster obtained convincing evidence that there is an ionizing radiation coming down from on high, and by 1926 the scientific world was on the whole convinced of the existence of cosmic rays.

An outstanding example of an ionization chamber now in use for the continuous recording of cosmic ray intensity is the so-called Carnegie Model C, designed by Compton, Wollan, and Bennett in 1934. In this instrument the cosmic ray ionization in a 19.3-l sphere of purified argon compressed to 50 atmospheres is balanced against the ionization in a small chamber due to the beta rays from a uranium source of adjustable position. The collecting electrode, common to the large chamber, whose wall is at +250 v, and to the balancing chamber, whose other electrode is at −250 v, is connected to a Lindemann electrometer, the position of whose needle is recorded photographically through a microscope. The use of balancing makes the readings largely independent of voltage and temperature variations. With its 10.7-cm lead shield around it, this instrument has an average cosmic ray current at sea level of about 2×10^{-13} amperes, corresponding to about 15 fast particles per sec. About once a day there is a "burst," corresponding to the simultaneous passage of more than 500 fast particles.

An extremely useful wartime development in ionization chamber technique is the use of electron collection coupled with fast amplifiers. The leaders in the application of this technique to cosmic ray problems have been Rossi, Bridge, and Williams, who have thereby made important advances in our knowledge of high energy nuclear interactions. It is possible to rid argon of electronegative impurities, so that the electrons formed in the ionization process are collected free rather than attached. Their drift velocity in the direction of the applied field is on the order of 1000 times greater than those of the massive ions. Under appropriate conditions of field geometry and gas filling, a fraction of the total pulse height exceeding 90% is attained in a few microseconds. This makes possible the use of ion chambers in relatively fast coincidence with other chambers and counter tubes. Furthermore, the same workers, together with Hazen, have shown how the shape of the ionization pulse, as photographed on a fast cathode ray oscillograph sweep, gives information on the initial spatial distribution of ions, so making it possible to distinguish between bursts due to many fast particles spread through the chamber and bursts due to "stars" of a few heavily ionizing particles.

The ionization chamber is merely the most venerable of the many instruments now used in cosmic ray research, each of which has been responsible for tremendous advances. The instruments of cosmic ray research are the instruments of nuclear physics, just as, for example, the instruments of conventional astronomy are those of optics.

The most striking feature of cosmic ray nuclear physics is the low intensities with which one has to deal. In the Carnegie Model C ionization chamber that I mentioned the flux of penetrating particles through a sphere 33.2 cm in diam is only about 15 per sec at sea level in high latitudes. The increases in intensity at very high altitude do not exceed several hundred times; it is sometimes necessary, on the other hand, to go below ground or water, where the intensities are decreased by similar factors. A second feature of cosmic rays is their heterogeneity in composition, energy, and direction. This means that as a rule the more clean-cut in design an experiment is, the longer will it take to obtain statistically significant data. A third peculiarity of cosmic

rays is their relative constancy, a feature which atones to some extent for the first two by making it possible to extend the experiments in time. Thus, in cosmic ray work one needs detectors of large size that function reliably over long periods of time. It is desirable, therefore, in a counter experiment to measure concurrently all the rates that one needs to know in order to decide whether the data are reliable. Thus the amount of apparatus devoted to monitoring often exceeds in bulk the apparatus needed for measuring the counting rate with which the experiment is concerned. In this pioneering branch of nuclear physics, one is out alone on the frontier; there is little established knowledge to go by, and one must take infinite pains to be sure that an effect one finds is not due to some equipment failure in the middle of the night or to an erratic behavior which might fail to show itself during an occasional test. It is particularly useful in this regard to record all counts on the moving strip of an operation recorder.

Certainly one of the most fruitful recent developments in cosmic ray instrumentation has been the application of electronic techniques to the sorting out of pulses, as regards time of occurrence and amplitude. The physicist now has at his disposal a potent arsenal of basic circuits for this purpose. Many of these circuits were developed before the war, but it took contact with the radar and atomic bomb projects to bring home to American physicists the possibilities of large scale application of electronic circuitry.

Dynamic Accuracy in Temperature Measurement

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The dynamic accuracy of a measuring instrument is concerned with its behavior under changing or dynamic conditions; likewise, its static accuracy is concerned with its performance under static conditions. Since it is relatively easy to define the static test conditions and to reproduce them whenever necessary, the usual accuracy specifications are limited to the static accuracy.

All practical temperature-measuring elements are imperfect dynamically simply because some heat is required to change their temperature and there is only a finite surface area through which the heat can flow. Consider a temperature-measuring element or bulb having a heat capacity of 0.004 Btu per °F and a surface area of 0.024 sq ft. If this element be immersed in a fluid flowing at such a velocity past the surface that the coefficient of heat transfer is 50 Btu/hr/°F/ft^2, the dynamic characteristics may be established. If the temperature is increasing at a rate of 20° F per min, the amount of heat flowing into the element is:

$$q = (20)(60)(0.004) = 4.8 \text{ Btu/hr.}$$

All of this heat must flow through the fluid film surrounding the bulb and, since the rate of heat flow is constant for a given rate of temperature change, the temperature drop over the film may be calculated from the steady state heat transfer equation

$$q = h\,A\,\Delta T$$

$$\Delta T = \frac{q}{hA} = \frac{4.8}{(50)(0.024)} = 4° \text{ F.}$$

Thus, in order to keep the element temperature rising at a rate of 20° F per min, the fluid temperature must remain 4° F higher. In this example, the dynamic error of measurement is 4° F. Similarly, an 8° F drop would be required to cause the element to change twice as fast, or 40° F per min. The dynamic error then varies with the rate of temperature change of the thermal element, so it is generally more convenient to express the dynamic characteristics of a given element in a given medium as the ratio of the dynamic error to the rate of temperature change. This ratio Z has the dimensions of time and is called the "dynamic lag."

$$Z = \frac{(\text{dynamic error})}{(\text{rate of change})} = \frac{4}{20} = \frac{8}{40} = 0.2 \text{ min.}$$

When defined in this way the dynamic lag is in fact the time by which the thermometer reading lags the true temperature when both are changing at a constant rate.

Reduction of dynamic error. In terms of the bulb heat capacity, C, its area A, and the heat transfer coefficient h, the dynamic lag is

$$Z = \frac{C}{Ah}.$$

This equation indicates some of the possibilities for reducing the dynamic lag and thus improving the dynamic accuracy. Any increase in the coefficient of heat transfer produces a corresponding decrease in Z. This means that the bulb should be located at a point where the fluid velocity is high, since h increases approximately as the square root of the velocity. By the same token, the coefficient of heat transfer is much greater in agitated liquids than in gases or even vapors at low velocity, so if a choice exists the better medium should surround the bulb.

Another possibility of reducing the lag is to change the thermal element to reduce its heat capacity or increase its area, that is, reduce the value of C/A. The most common method is to reduce the diameter of the element. Occasionally, finned bulbs are used, although the improvement that can be obtained is limited. In general, for bare bulbs or thermocouples, without a protecting well, the internal thermal resistances are negligible compared to the fluid film resistance and the element can be considered as homogeneous and characterized by a single heat capacity and a single thermal resistance as was done in the previous example. Actually, there are small thermal resistances throughout the element which add a fraction of a second to the lag caused by the fluid film, but the latter are much larger, varying from a second or two up to several minutes. This is not the case for thermal elements installed in protective wells, unless exceptionally good thermal contact exists between the sensitive element and the well, since an air space of a few ten-thousandths of an inch between the two can

add many seconds to the dynamic lag. In addition, a more complex "two capacity" lag results which will not be considered in this paper.

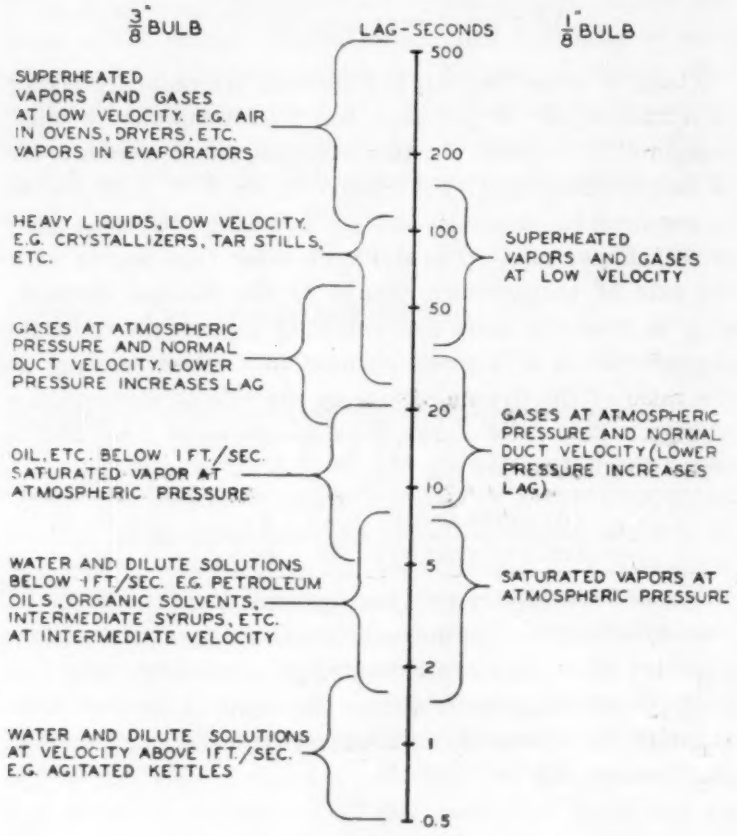
3/8" BULB
LAG - SECONDS
1/8" BULB
500
200
100
50
20
10
5
2
1
0.5
SUPERHEATED VAPORS AND GASES AT LOW VELOCITY. E.G. AIR IN OVENS, DRYERS, ETC. VAPORS IN EVAPORATORS
HEAVY LIQUIDS, LOW VELOCITY. E.G. CRYSTALLIZERS, TAR STILLS, ETC.
GASES AT ATMOSPHERIC PRESSURE AND NORMAL DUCT VELOCITY. LOWER PRESSURE INCREASES LAG
OIL, ETC. BELOW 1 FT./SEC. SATURATED VAPOR AT ATMOSPHERIC PRESSURE
WATER AND DILUTE SOLUTIONS BELOW 1 FT./SEC. E.G. PETROLEUM OILS, ORGANIC SOLVENTS, INTERMEDIATE SYRUPS, ETC. AT INTERMEDIATE VELOCITY
WATER AND DILUTE SOLUTIONS AT VELOCITY ABOVE 1 FT./SEC. E.G. AGITATED KETTLES
SUPERHEATED VAPORS AND GASES AT LOW VELOCITY
GASES AT ATMOSPHERIC PRESSURE AND NORMAL DUCT VELOCITY (LOWER PRESSURE INCREASES LAG)
SATURATED VAPORS AT ATMOSPHERIC PRESSURE

FIG. 1. Normal thermal lags.

Even with good installation practice and the use of bulbs with low C/A values, the lag is often larger than can be tolerated and measurement of transient changes cannot be made with any accuracy or control results are miserable. In Fig. 1, approximate values of normal bulb lags are given for a variety of conditions for bulbs $\frac{3}{8}$ in. and $\frac{1}{8}$ in. in diam. These values are not limited to liquid- and gas-filled thermal systems; they apply equally well to a bare thermocouple $\frac{1}{8}$ in. in diameter or to a thermocouple welded into a $\frac{3}{8}$-in. tube, since the C/A values will be essentially the same.

This table shows that bulb lags are often quite large. One should also remember that the possibility of using small-diameter bulbs is generally limited to noncorrosive and nonerosive gases and vapors; furthermore, a $\frac{3}{8}$-in.-diam bulb is often too frail to stand the mechanical forces encountered in flowing streams of viscous liquids.

Derivative compensation for dynamic lag. In view of the rather obvious requirements for faster speed of response, it seems desirable to point out another way of improving the dynamic accuracy of thermal systems.

As in most compensation problems, the method is quite simple. A quantity proportional to the error is measured and the appropriate correction is applied to the instrument reading. In this case, the error is the temperature difference between the sensitive element and the temperature of the medium:

$$\Delta T = \left(\frac{dT}{dt}\right)\frac{C}{Ah} = Z\left(\frac{dT}{dt}\right).$$

Since the error is proportional to the rate of change of bulb temperature, dT/dt, one merely needs to measure this rate of change, multiply by the appropriate bulb lag and add this correction to the bulb temperature to obtain the corrected or true temperature.

The pneumatic temperature transmitter offers an easy solution to this problem. Consider the simplified circuit of a force-balance pneumatic transmitter as shown in Fig. 2. A gas-filled thermal system has its bulb immersed in the process medium and the force resulting from the gas pressure on the diaphragm is balanced by the biasing spring and the force from the balancing bellows. An increase in bulb temperature, for example, will move the baffle away from the nozzle, decreasing the nozzle back pressure and increasing the relay valve output pressure (P_o). This increase in output pressure results in a flow

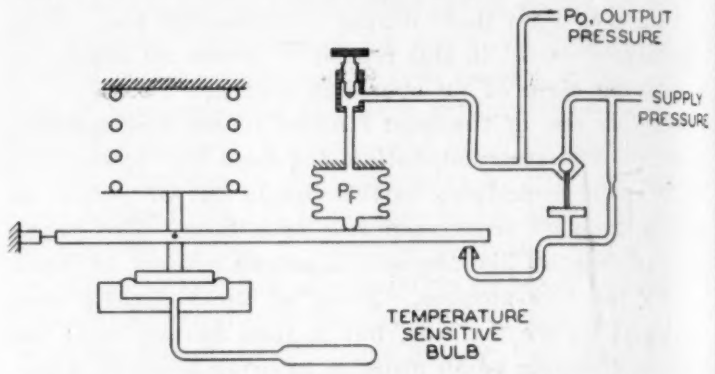

FIG. 2. A simplified schematic of a Transaire force-balance temperature transmitter.

into the balancing bellows through the open-needle valve and applies an opposing force to the diaphragm of sufficient magnitude to substantially prevent movement of the diaphragm and baffle. The change in balancing bellows pressure P_F (and the output pressure P_o) is then directly proportional to the change in bulb pressure, which is in turn proportional to its temperature.

By suitable calibration, a balancing bellows pressure change of, say, 3 to 15 psi can be made to correspond to the desired temperature span of the transmitter. The output pressure is then transmitted to a pressure receiver also having a span of 3 to 15 psi. Ambient temperature and barometric pressure compensation would, of course, be required in any complete instrument, although they are not shown.

Returning to the derivative or "dynamic compensation" for thermal lag, we note that the rate of pressure rise in the balancing bellows is directly proportional to the rate of temperature rise of the gas-filled bulb. Increasing pressure in the balancing bellows will require the flow of air into the bellows. In fact, the rate of flow is directly proportional to the rate of pressure rise in it. Introducing a capillary or needle valve restriction in the line to the balancing bellows will result in a pressure drop which is proportional to the rate of temperature rise of the bulb.

The output pressure of the relay valve will then be equal to the balancing bellows pressure plus this pressure drop. Suitable adjustment of the restriction allows selection of the appropriate lag correction factor to neutralize the dynamic error. The adjustment dial on

the restriction can, in fact, be calibrated directly in terms of the time lead (or dynamic compensation factor) introduced by it.

Adjustment of the dynamic compensation factor can be made in a number of ways. Generally, the lag of the thermal element can be estimated from tables with sufficient accuracy and the dynamic compensation factor is set equal to this lag.

It is believed that the use of a derivative transmitter to achieve dynamic compensation for the inevitable lag of thermal elements offers a valuable and unique tool in the field of temperature measurement and control which makes possible a degree of speed and accuracy not previously obtained.

Velocity and Flow Measurements with an Improved Thermal Instrument

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Hampton, Virginia

Precise measurement of the velocity of free air currents moving at rates as low as 5 ft/min has always been a difficult problem. It is one, however, that is constantly present in a wide variety of applications such as meteorology and microclimatology research, air conditioning, heating and ventilating work, measurement of rate of flow in gas or air systems, hay and tobacco drying processes, and general process control.

A new type of electrical anemometer that has recently been developed for applications such as these allows velocities as low as 5 ft/min to be determined with accuracies previously limited to high velocity measurements. The new instrument, which is known as an Air Meter, operates by placing a heated precious-metal thermopile in the airstream. The flow of air past the thermopile tends to bring the thermopile wire, consisting of a succession of thermojunctions, to the same temperature throughout. The thermal differences between these junctions induce a thermal direct voltage proportional to the temperature differences. Thus, flow of air past the thermopile tends to reduce this temperature difference and, therefore, to reduce the direct voltage generated by the thermopile.

The thermopile, or sensitive element of the anemometer, is made up of alternate sections of thermocouple materials butt-welded to obtain a continuous wire. This wire is then heated by passing an alternating current through it. Cold junctions of the thermopile are obtained by attaching alternate junctions to copper mounting studs, thereby supplying sufficient heat conductivity away from the junctions to keep them at ambient temperature. The other junctions, not in contact with the copper studs, are heated by the alternating current. Alternate junctions therefore become the hot and cold junctions of the thermopile.

Normally, maximum voltage is obtained with zero air velocity, and zero output represents a large cooling effect by a high air velocity. However, when high accuracy is desired over a wide range of velocities, a second series of thermocouples can be arranged with opposite polarity and shielded from any air currents. With these couples arranged to buck the voltage from the velocity pickup thermopile, zero voltage output is obtained for zero air velocity and full-scale indication of the indicating or recording instrument is obtained for the particular air velocity desired. Sensitive instruments of this type are well suited to process control, the rapid response of the electric signal operating controls and giving warning of deviations.

The principle of placing a heated thermopile in an airstream for determining air velocities has many advantages over older types of anemometers. Thermal anemometers have no moving parts to introduce frictional errors, which are very important in low velocity measurement. Also, they are not affected by icing. This thermopile type anemometer has additional advantages over the usual hot-wire types in that the indicating or recording instrument consists of a measurement of direct current voltage instead of a small change in resistance. The errors introduced by lead resistance are thus much less. Errors introduced due to change in air temperature are compensated for, since both cold and hot junctions are equally affected by any change in ambient temperature. The instrument measures the temperature difference between these junctions, all of which are exposed to the airstream. Likewise, radiation effects tend to cancel.

A two-thermocouple arrangement which lends itself to an inexpensive type of construction has been incorporated into a standard low-cost model which has proven very versatile and reliable in laboratory and field use. The indicating meter is small and can easily be held in the palm of the hand while taking readings. The thermopile element is a separate probe which may be plugged directly into the indicating meter, or which may be used at the end of graduated extension wands or cables. For applications requiring extreme sensitivity and accuracy for very exacting research measurements, a larger instrument has also been developed.

Experience has proved this type of thermal anemometer to be exceptionally stable. One instrument has operated continuously for a year in the laboratory and a second instrument, designed for indication of nondirectional air flow, has operated for the same period on top of a building and has consistently indicated wind velocity without failure or zero shifts.

The Air Meter is well adapted to remote recording on standard strip-chart potentiometers or other standard types of indicating or recording instruments which operate from direct voltage. The ability of anemometers of this type to measure extremely low velocities, combined with their inherent stability, ease of operation, low power requirements, and adaptability to remote indication or recording, suggests many applications of a widely varying nature.

Light Rays Can Be Tools

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The supreme precision of a beam of light is an old story. It is straight—regardless of the distance it travels. It exerts no pressure on the objects it falls upon. It does not wear. And it is exact, furnishing the universal standard for all measurement.

But if these properties of light are themselves an old story, their applications in industry constitute a new one. For not until light has been harnessed by optics are these properties useful as a means of gaging in the shop or plant. Yet once harnessed, light rays can be tools—can, for example, measure a rise of 0.002 in. in a distance of 30 yd, measure the angle between two related surfaces to an accuracy of less than one sec of arc, or magnify an object to a degree where one operator can check 18 separate dimensions to tolerances of 0.0005 in. at a rate of 280 parts an hour—an operation that formerly required 9 operators and 16 mechanical gages.

Each of these applications applies familiar principles of light. In one case a beam of light is used as a perfectly straight line of reference. In another, this beam is put to work by applying the simple geometric principle that the angle of reflection equals the angle of incidence. In the third, advantage is taken of the ability of optics to change scale. Which property is pertinent depends on the product in manufacture, how it is made, how it is inspected, and how it is used.

This does not mean, however, that a large research program in optics is a prerequisite of using light as an industrial tool. Certain basic optical designs are applicable to the majority of industrial uses because of their universality and their versatility. These fall into three major classifications: (a) Autocollimation—in which a beam of light is reflected back on itself from a reference surface on the work, for checking the angle between two planes, however far separated, to any desired accuracy. (b) Telescopic alignment—employing such devices as double-ended telescopes and divided-aperture objectives, for establishing by absolute methods a line of sight in fixed relation to a plane and then measuring displacements of distant targets from it. (c) Projection of silhouettes and illuminated surfaces to a screen, where they can be measured and examined at any magnification —by eye, photocell, or by photography.

Instruments falling under the classification of autocollimation are for the measurement of angle. Everyone knows that to see his image in a mirror he must stand directly in front of the mirror, and this principle is the basic premise of the autocollimator. Yet these instruments are capable of working to angular tolerances of less than one sec of arc: i.e., to an angle equivalent to a rise of 0.001 in. in a distance of 17 ft.

Fig. 1 is a cross-sectional view of an autocollimator and target mirror mount used to check flange faces on

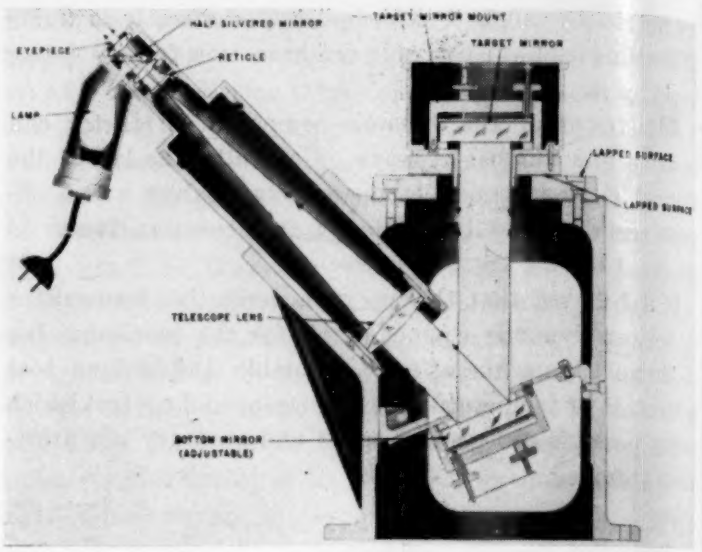

FIG. 1.

the ends of a tube for parallelism. The instrument is self-checking, since the reticle image will coincide exactly with the reticle itself when the surface of the mount is placed directly on the surface of the instrument. Once the instrument has been zeroed in this way, the tube may be placed on the surface of the instrument and the target mount placed on the opposite end of the tube. Any deviation from parallelism in the flange faces will be manifested by the amount the reticle image is offset from the reticle.

Modifications of this instrument may be used for checking many other types of angular measurement, or its principles may be employed in special instruments for complex tasks by combining autocollimation with other optical devices, such as telescopic aligners.

The telescopic aligner, shown schematically in Fig. 2,

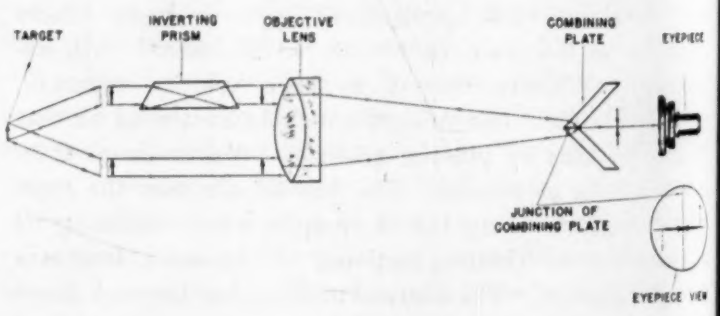

FIG. 2.

establishes by absolute methods a line of sight in relation to a plane and will measure displacements from this line to ten-thousandths of an inch. The target itself may be regarded as an illuminated vertical arrow which is viewed under two different conditions, as an erect and as an inverted image. The objective lens directs these images to a common focal point and when the target is on the level of the lens axis, the images coincide. Conversely, when the target is displaced from the lens axis, the images move in opposite directions. Thus the target may be used to establish a position along a line with complete accuracy and regardless of distance.

The repetitive accuracy of measurement is remarkable. Readings can be repeated to a tolerance of ± 0.0003 in. with the target at a distance of 20 ft from the aligner.

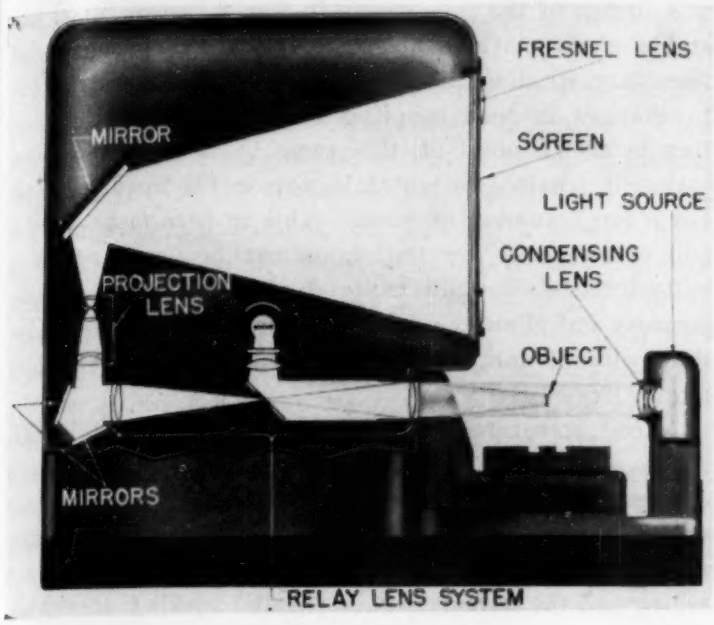

FIG. 3.

With the target at a distance of 100 ft, measurements can be made with a tolerance of ±0.003 in.

While this instrument was designed primarily for aligning planer beds, it can undoubtedly be applied to the solution of other problems involving heavy machine tools and other massive equipment.

The third major classification of optical instruments, that of contour projection, introduces the only use of optics for gaging mechanical components that has been employed to any extent in industrial inspection. However, the practically limitless applications of this tool to inspection problems have not been generally realized.

All contour projectors work on the same basic principle and are made up of a light source, object, lens, and

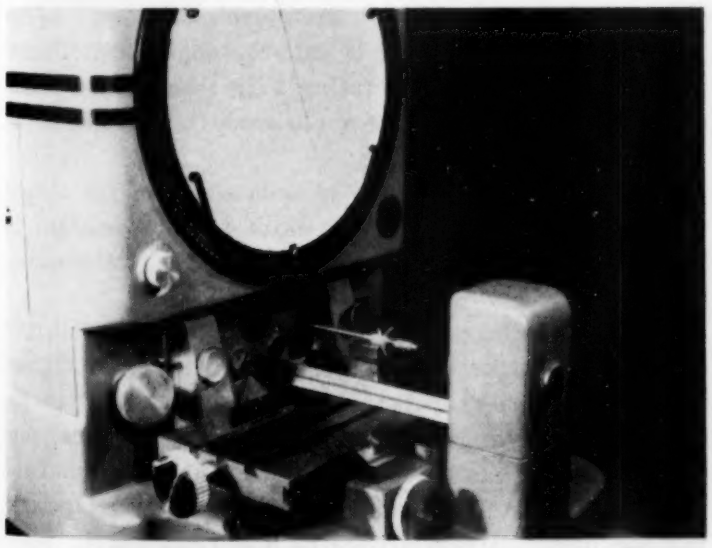

FIG. 4.

screen. However, if this simple system is supplemented with any of several optical elements, its versatility is greatly increased. The first of these elements is a relay lens (Fig. 3) and the second a Fresnel lens, mounted behind the screen.

This Fresnel lens provides increased screen brightness by concentrating the cone of light coming from the screen into a cylindrical beam directed at the operator. This permits the use of the projector in lighted rooms without hoods or curtains and, with the relay lens, helps to provide surface projection of brilliance hitherto customary only in shadow projection.

There are many instances in which a work piece may be recessed or obstructed, or measurement of surface details must be made. In such cases the surfaces themselves can be projected as a bright image in contrast with the more familiar contour, or shadow, image. Here the relay lens affords a unique opportunity for obtaining maximum illumination. An elliptical mirror may be inserted in the relay lens system (Fig. 3) and light from a 1000-w lamp directed through the front lens to the object. The object reflects the light back in turn, but the reflected image converges and a hole in the mirror permits the image to pass through and be directed onto the screen.

So successful is this system that it is possible actually to project the surface of black Bakelite molded parts.

The relay lens also serves two other functions of major importance, both of which increase the scope and versatility of contour projection. It permits an 8-in. clearance between the work piece (Fig. 4) and the first lens of the system, at all magnifications, providing ample space for awkward parts or for efficient staging fixtures. It also transfers an image at 1:1 magnification to the rear of the instrument, where projection lenses of any desired magnification may be mounted.

Here again, the versatility of the science of optics is illustrated, incorporating in a single system elements which can do, not one, but a variety of tasks, with the inherent advantage of a precise, pressureless, and predictable gaging element.

The Differential Transformer as Applied to Instrumentation

W. D. Macgeorge

Automatic Temperature Control Company, Philadelphia

The measurement of substantially straight line motions is an important factor in the science of instrumentation: for example, the measurement of the displacement of a bellows or a diaphragm, the motion of a float, the tip travel of a Bourdon tube, and the tilt of a weigh beam. Various means have been devised for converting these displacements into signals suitable for electrical transmission, but only in recent years has the differential transformer been used to any extent in this field.

It is the purpose of this paper to treat with only two general phases of this topic: (1) the basic design of differential transformers: and, (2) the circuits which permit their application to the measurement of instrumentation variables such as pressure, flow, and force.

A differential transformer consists essentially of a primary coil, two secondary coils, and an armature of magnetic material. The primary coil is energized from a suitable source of alternating current, the two secondary coils are connected so that their output voltages are 180° out of phase and the armature is located so that it can alter

the relative flux distribution which exists between the primary coil and the two secondary coils. (See Fig. 1.)

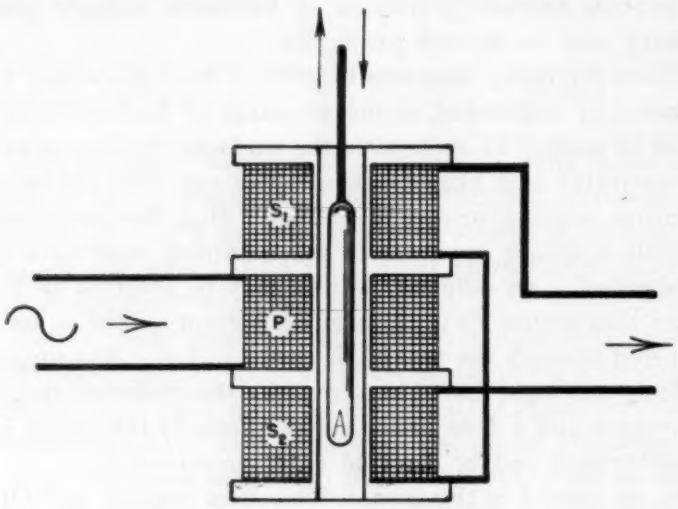

FIG. 1. Differential transformer.

Motion of the armature *A* toward secondary coil *S*1 results in an increased output of one phase and motion of *A* toward *S*2 results in an increased output of the opposite phase. If *S*1 and *S*2 are identical coils and *A* is located so that each receives an equal amount of flux, the voltages induced in these secondary coils will be equal and out of phase and a theoretical output of zero will result. This condition denotes the null, or balance point of the differential transformer.

Obviously, the electrical energy could be applied to coils *S*1 and *S*2 and the differential output obtained from coil *P* without basically altering the transformer structure or the results obtainable. This has been done in some designs.

In accordance with the previous descriptive data, the differential transformer becomes essentially a self-contained device for producing an electrical output, isolated from the source of power, which may be controlled in both amplitude and phase by an adjustment of the flux distribution within the transformer. It should never be considered as part of a bridge circuit, but only as an isolated source of controlled alternating current.

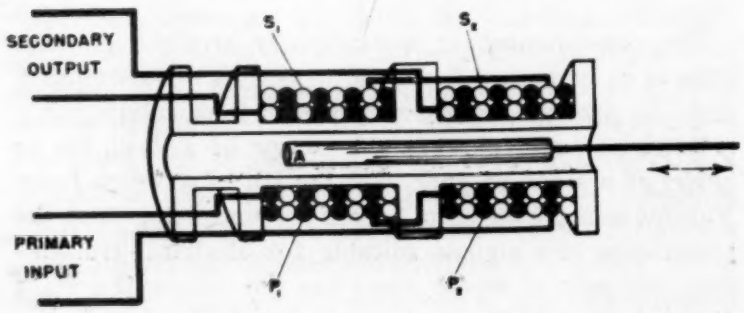

FIG. 2. "Atcotran" type of differential transformer.

Investigation over a period of years and numerous field tests have led to a design which combines the desirable features of a differential transformer into a structure which can be reproduced accurately. This device is shown in Fig. 2. The coil structure, divided into two main sections, contains four windings, two of which serve as the primary while the remaining two act as the secondary. The small section at the left end of the coil form is used to house the necessary interconnections and lead wire terminations.

A design of the type shown in Fig. 2 insures equal and stable electrostatic coupling between the primary and secondary windings and minimizes temperature drift due to changes in such coupling. Uniform magnetic coupling is also insured on this same basis and this factor makes it possible to maintain reasonable linearity without a large number of turns. This in turn means that a coil of relatively low impedance can be produced which will adequately match into standard audiofrequency transformers and allow the use of relatively long transmission lines without danger from stray pickup and phase shift due to line capacity.

A coil structure of this type is also quite versatile. Although the unit is normally used with the primary coils connected series aiding and the secondary coils connected series bucking, this condition may be completely reversed, or the primary coils may be connected parallel aiding and the secondary coils parallel bucking, etc. Also, since the unit is essentially a two-coil balanced structure, it is quite possible to bring out a center tap between the two adjacent windings and use one section as an induction bridge. There is an almost endless list of workable combinations when one considers that more than two windings can be placed in each section.

Some advantages inherent in a well-designed differential transformer are:

(1) Negligible phase shift throughout the operating range. In inductance bridge circuits the resistance of the coils remains constant while the inductance of these coils varies over a considerable range. The resulting shift in the resistance and inductance vectors causes a very substantial phase shift which must be taken into consideration in the design of any indicating circuits. In a differential transformer such as the "Atcotran,"[1] the change in inductance for an armature motion of ± 0.1 in. (twice the normal range) is entirely negligible. Therefore, servomechanisms operating with these transformers need not be compensated for phase shift throughout the indicating range.

(2) The source of power is isolated from the output circuit. This feature allows units to be combined in various ways and to perform many useful mathematical functions.

(3) A high degree of linearity and reproducibility of output with respect to armature displacement is obtainable. A linearity of better than $\pm 0.05\%$ may be expected from standard production run Atcotrans, and these units will match each other within $\frac{1}{2}\%$ without the use of calibrating resistors, or other means of compensating for normal irregularities in materials and in winding.

For comparison let us assume a single bonded type strain gage, connected into a bridge circuit and strained to approximately 0.003 in. per in. (about 100,000 psi stress in steel); it would yield an output of 0.0015 v per volt input for this range. A differential transformer over its normal maximum range of 0.300 in. would yield an

[1] Trade mark registered. Automatic Temperature Control Company, Inc.

output of .075 v, or an output advantage of 50:1 on a range basis of comparison.

To apply the differential transformer to a measuring problem a null type of circuit is recommended. (See Fig. 3.) In this circuit the output from the transmitting unit, $T1$, is 180 degrees out of phase with that of the balancing transformer, $T2$, and the difference voltage is fed through an amplifier to one phase of a two-phase servomotor. The other phase of this motor is energized continuously from the line. When both differential transformers are producing equal, out-of-phase voltages, there will be no input to the amplifier and the motor will be at rest. However, if the armature of transformer is displaced slightly, a restoring signal will be produced which will cause the motor to rotate and return the system to balance.

The reasons for using a null balance system are:

(1) It is unaffected by line voltage changes. If there is no stray 60-cycle pickup in the system, it will be unaffected by normal line voltage changes and even an excessive pickup voltage, equal to 10% of the total signal at full scale, would only cause a 1% change in reading for a 10% change in line voltage. In normal systems the pickup voltage will always be less than 1% of the full scale signal.

(2) It is relatively unaffected by resistance changes in the connecting leads. The addition of resistance to either the primary or secondary circuit will have little effect on the balance of the circuit, although its sensitivity will be affected. This means that changes in coil resistance due to heating will not unbalance the circuit.

The following information may be of value in the application of null balance circuits:

(1) Electrical zero check. If a shunt is connected across terminals 3 and 4 of the transmitting differential transformer (See Fig. 3), its output will be zero and the

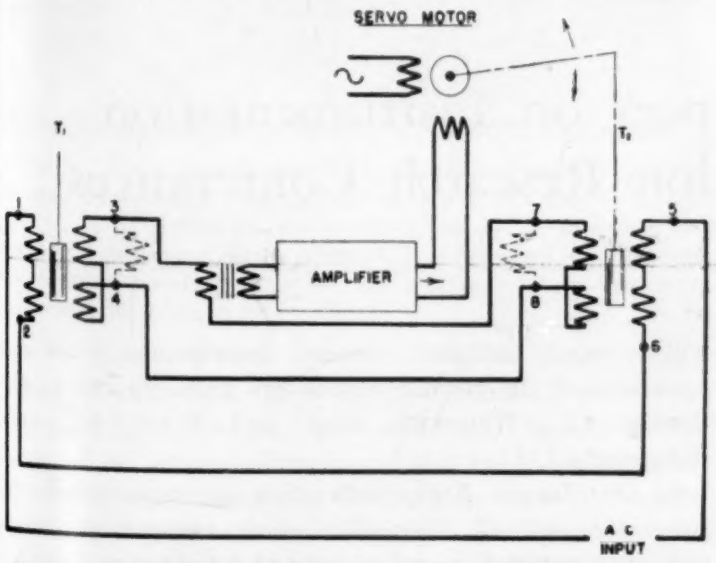

FIG. 3. Null balance circuit for differential transformers.

servo system will come to balance at the null position of the balancing differential transformer.

(2) Electrical range change (ratio control). If a resistor is connected across terminals 7 and 8 of the balancing transformer, $T2$, (See Fig. 3) its output will be reduced. When the output of $T2$ has been reduced in this manner, the servomotor will now have to move farther to balance a given change in input voltage from the transmitter and the effective sensitivity of the servomechanism will have been increased. This method has been successfully used for sensitivity ratios up to 10:1 and may also be used as a calibrating means.

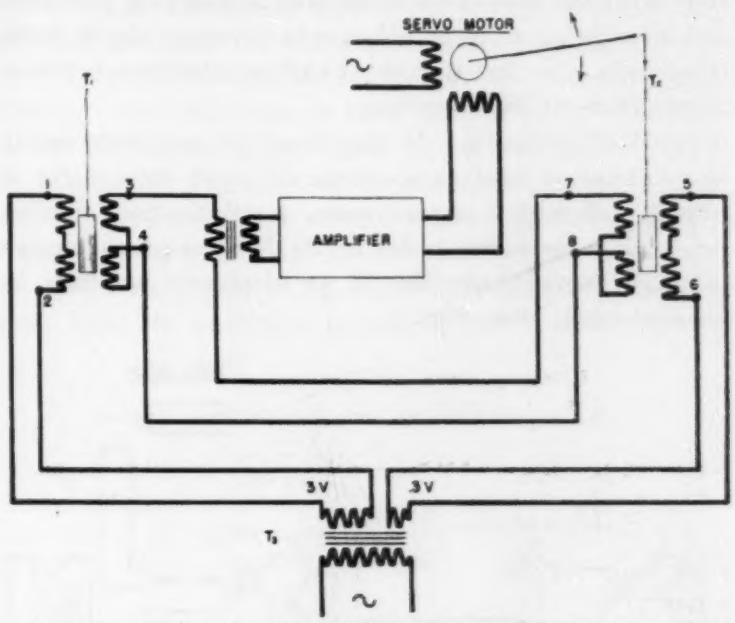

FIG. 4. Null balance circuit with transformer type range change.

It is possible to obtain similar results by means of transformers instead of by means of shunts. See Fig. 4. Here the input voltages to the two differential transformers are set up as a predetermined ratio by the supply transformer, $T3$. Ratios as high as 40 to 1 have been used with a circuit of this type, although changes in lead resistance affect the ratio to a certain extent.

(3) Algebraic summation. See Fig. 5. The use of more than one differential transformer as a transmitter

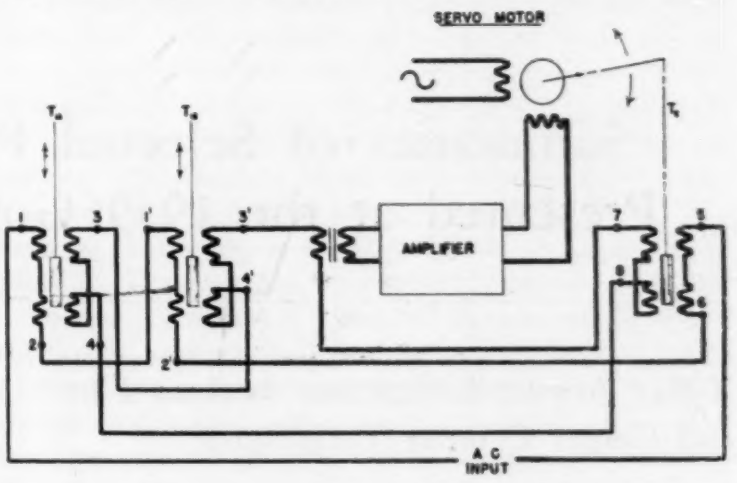

FIG. 5. Algebraic summation circuit.

is both feasible and useful. When transformers $T1a$ and $T1b$ are properly connected, their outputs are algebraically summated in such a way that their output voltages represent the magnitude to be measured and their phase becomes the plus and minus sign for this magnitude. The servomechanism balances out the resulting signal and indicates the algebraic sum of the two variables controlling transformers $T1a$ and $T1b$. Up to six transmit-

ters have been successfully summated by this method without difficulty. A typical application is the use of four Atcotran load cells to support a weighing platform and a weighing servo to indicate the average signal from these cells. In this way the weighing platform becomes independent of load position.

(4) Multiplication. If the input of one differential transformer is used as a source of input voltage for a second differential transformer, multiplication results. Since adequate power is not available in one transformer to drive another, the use of an electronic amplifier is recommended. See Fig. 6.

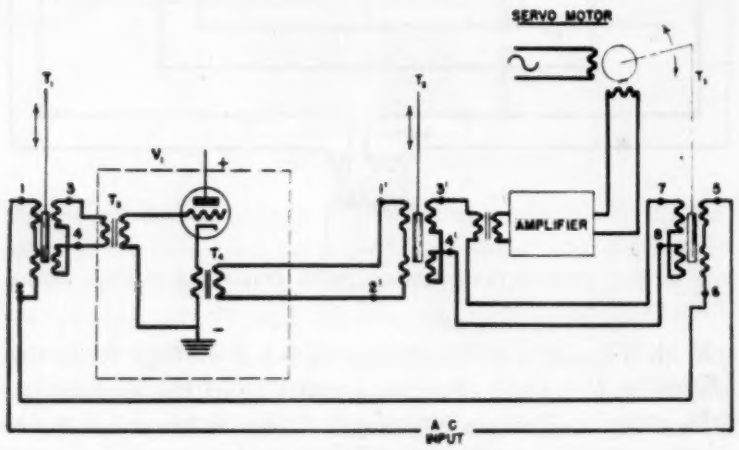

FIG. 6. Multiplying circuit.

This device has been used for compensating the output of a flow meter for changes in pressure and for other similar uses.

(5) Use of null balance circuits. In making connections between the various components of differential transformer null balance circuits, the author has standardized on the following procedures: (a) use of twisted pairs for all primary circuits; (b) use of shielded, twisted pairs for all secondary circuits, for runs over 50 feet; (c) number 20 BS gage, stranded wire is of ample size for most installations. The wires should be run in conduit but never in the same conduit with power lines.

If properly installed, transmitters and receivers may be several thousand feet apart. Special 400-cycle systems requiring only a *50 millivolt input* signal to the transmitter have been used for hazardous locations.

Although the differential transformer is still a newcomer in the instrument field, there are some standard instruments available. These include circular scale indicators with ¼% of reading accuracy (above 10% of scale) and a ten-to-one sensitivity switch; multichannel optical indicators with three automatically selected scales, a scale length of 84 in. and a 2-sec speed of response; strip chart, round chart single and multipoint recorders, controllers, etc. The switching of various input circuits into one indicator, or recorder, such as is normally done with thermocouple circuits, is standard practice with most differential transformer instruments. Transmitters for pressure, flow, density, level, motion, etc., are also available as either standard, or custom built devices.

While it is obvious that a direct indicating, meter type of instrument may be used with a differential transformer instead of a servodriven, null balance device, no time will be devoted to these units at this time. It is only with the null balance systems that the remarkable accuracy and stability of the differential transformer can be realized.

In general, differential transformer instrument systems should be used (1) whenever highly accurate measurements of motions are required, (2) where minute forces are available and friction of any kind would be a disadvantage, (3) where electrical transmission of various variables is a requisite, and (4) where it is desired to express certain mathematical functions electrically.

Summaries of Selected Papers on Instrumentation Presented at the 1949 Gordon Research Conferences

X-Ray Powder Diffraction Analysis Film and Geiger Counter Techniques[1]

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In this note a few of the techniques and new instrumentations for X-ray powder diffraction which have been developed at this laboratory during the past six years will be briefly outlined. General descriptions of the applications of the powder method are given by Bunn (*4*), Guinier (*7*), Hanawalt, Rinn and Frevel (*9*) and Straumanis (*12*).

In the Norelco X-ray diffraction aparatus the X-ray tube is sealed off, thus eliminating vacuum problems, vertically mounted, water cooled and full-wave rectified to aid Geiger tube work. The voltage and/or current may be continuously varied. One feature of the apparatus is that four pieces of accessory apparatus, including one or two spectrometers, can be operated simultaneously.

Powder Cameras. The design and use of Debye-Scherrer powder cameras are deceptively simple. In order to ob-

[1] Based on papers given at meetings of the American Society for X-Ray and Electron Diffraction, 1947–49.

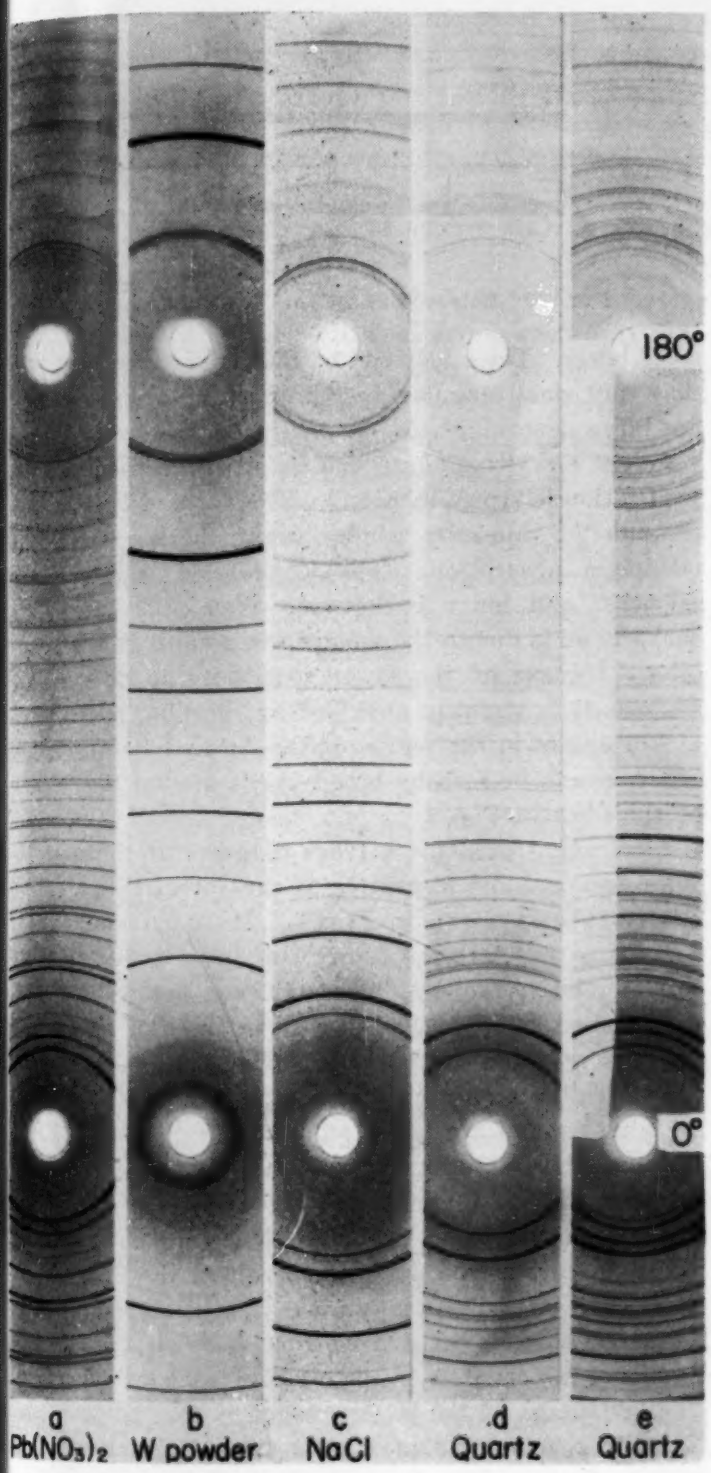

FIG. 1. X-ray powder photographs, 114.6 mm diam powder camera, Straumanis film mounting, CuK, 40 kvp, 20 ma, $\psi = 2°$. *a–d*, 0.0006-in. nickel filter, specimen mounted on 0.003-in. Lindemann glass fibre, 8 hr exposure; *e*, filter on side of film, specimen packed in Lindemann glass capillary with 0.012-in. bore, 1 hr exposure.

tain the excellent films shown in Fig. 1, certain techniques, all quite well known but not commonly practiced, are required, as much as a good camera. The mechanical design of the camera allows rapid and exact centering of the specimen and mounting of the film, exact alignment and repositioning with the X-ray tube, and easy manipulation in practice (*3*). The collimator system has been carefully computed and designed to give a minimum and almost uniform background from air scatter, no "blind" region on the film from about 5° to 175° 2θ, complete absence of scatter from metal parts of the camera or collimator, excellent line shape, and good intensity and resolution (*11*).

Precise alignment of the collimator and exit port axes with the specimen rotation axis is essential and can be tested by photographing a very thin fibre of a heavily absorbing specimen. If the alignment is accurate, the diffraction arcs will be either evenly split doublets or smooth lines of equal thickness on both sides of the 0° film hole along the equator of the film. If the collimator system is misaligned, the arc will appear as a doublet on one side of the hole and a smooth line on the other or the lines of the doublets will be unequally spaced. This can be corrected by mounting both the collimator and exit port tubes in bushings, preferably of the cone-in-cone

TABLE 1

PROJECTED SIZES OF 10 × 1.2 MM FOCAL SPOT

ψ	Line focus	Spot focus
2°	0.04 × 10 mm	9.35 × 1.2 mm
3°	0.06 × 10 "	0.5 × 1.2 "
6°	0.12 × 10 "	1.0 × 1.2 "

type, whose position can be adjusted in the camera body. The adjustment is made, using a very thin glass fibre for a specimen and a magnifier fitted over the end of the exit port tube. We have found it useful to translate and rotate the specimen during exposure to obtain smoother lines and better relative intensities (*3*).

The focal spot of the new Norelco X-ray tube is 10 × 1.2 mm and the tube is constructed to allow viewing the target at grazing incidence. If ψ, the angle between the target surface and the axis of rotation of the specimen, is decreased from the conventional 6° to 3° or less, the projected size of the focal spot becomes small enough so that it can be used as the effective source slit and an actual slit is not required (*7*). The projected sizes are shown in Table 1.

The intensity as a function of ψ reaches nearly a maximum at 2°, with practically no increase at larger angles. For a given collimator with fixed divergence aperture the divergence of the beam increases as the projected size of the focal spot increases and hence the resolution decreases. The sharpest lines with maximum *peak* intensity are thus obtained at $\psi = 2°$. The divergence of the beam is limited by a circular aperture 0.5 mm diam, which in the case of the 114.6-mm-diam camera is 14 mm in front of the specimen. The full angular aperture with this arrangement is 0.4° in the vertical plane and 0.9° in the horizontal plane along the specimen axis. Although most camera tracks are set for $\psi = 6°$, the method can be applied by changing the track height and rocking the camera around the specimen axis of rotation.

Considerable care must be taken in specimen preparation (*12*). The crushed sample is passed through 200-mesh bolting cloth and is mixed with a few drops of collodion diluted 1:10 with amyl acetate. If the material has a high absorption it is mounted on a 0.003-in. Lindemann glass fibre which is rolled in the *wet* mix. Petroleum jelly may be used if the collodion dissolves the specimen. A 0.005-in.-to-0.008-in. fibre is used for materials with moderate absorption and a capillary for ma-

terials with low absorption. The decrease in exposure time and resolution caused by using a capillary instead of a thin fibre for a quartz specimen may be seen by comparing Fig. 1d and 1e. All of these films have been purposely overexposed for the illustration and usable films may be obtained with shorter exposures.

Geiger Counter X-Ray Spectrometer. This instrument, based on the original design by the Braggs (*2*), was introduced about seven years ago and has found wide use in university and industrial laboratories where relatively accurate measurements of intensity and high resolution must be conveniently made. Its usefulness for quantitative analysis has also been demonstrated (*5*). A divergent beam of X-rays and a relatively large flat specimen 10×20 mm are used with a Geiger tube replacing the film as detector. The specimen is equidistant between the focal spot, which is the source slit, and the receiving slit in front of the Geiger tube (*1, 6*).

The X-ray optical arrangement of the newest instrument (*8*) is illustrated in Fig. 2. The line focus ($\psi = 3°$) is

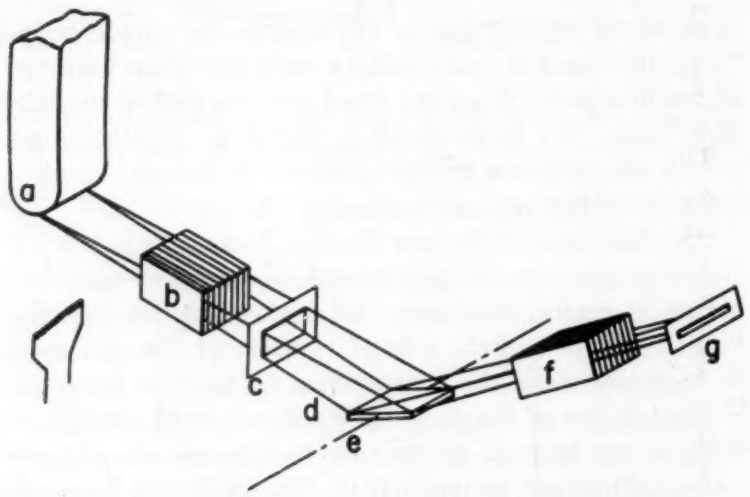

FIG. 2. Schematic X-ray optical arrangement of new spectrometer. *a*, X-ray tube line focus; *b*, *f*, Soller slits; *c*, divergence slit; *d*, Bragg focusing; *e*, specimen axis of rotation; *g*, receiving slit.

used with Soller slits (thin absorbing metal foils stacked in a parallel arrangement) to limit the divergence of the beam to a full angular aperture of 2¼° in the plane perpendicular to the plane of Bragg focusing. The best resolution is obtained with a receiving slit at least as small as the projected size of the focal spot. Scatter slits (not shown) prevent the Geiger tube from detecting radiation not scattered from the specimen. The Geiger tube arm scans in the vertical plane, the radius of the goniometer is 170 mm, and the scanning range is $-38°$ to $+160°$ 2θ. The diffraction angles may be read to 0.01° in manual operation or angular intervals marked on the strip chart in automatic recording. The goniometer gear arrangement rotates the specimen at one-half the angular speed of the Geiger tube so that the center of the specimen is always tangent to the focusing circle. The use of a focusing arrangement gives high resolution and high intensities, since large angular apertures in the plane of Bragg focusing may be employed. For the range 20°–80° 2θ the angular aperture is 1° and it is increased to 4° in the back reflection region where the intensities are very

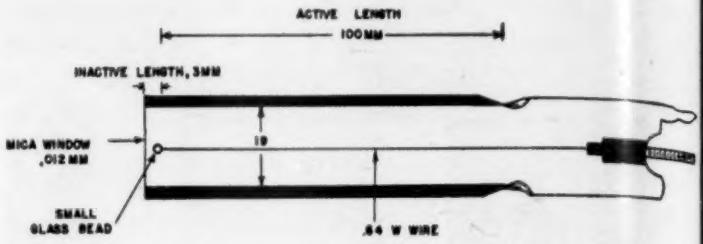

FIG. 3. Geiger counter for X-ray diffraction.

much lower. The sensitivity of the Geiger tube is so high that very small angular apertures may be used to measure large *d* spacings.

Geiger Counter Tube. The Geiger tube used for this application is shown in Fig. 3. The focused beam passes through the thin mica window along the wire anode for maximum absorption. The argon-filled counters give smoother and lower background than film (where the background is due to the shorter wavelength general radiation) because of the lower sensitivity in this region, whereas it is strongly absorbed by the film, particularly at low angles in the region of the Ag and Br absorption edges, as can be seen by broad bands around the 0° hole of the films in Fig. 1.

Electronic Circuits. A block diagram of the new circuits designed for measuring X-ray intensities with the Geiger tube is shown in Fig. 4. It is particularly important to regulate the X-ray supply in order to make correct relative intensity measurements, because the lines are scanned successively, whereas in the film method all lines are recorded continuously during the exposure.

The scaling circuit comprises eight scales-of-two which are plug-ins and are based on a modification of the conventional Eccles-Jordan type. The circuit has a resolving time of 6 to 7 microseconds (which is several times faster than currently available Geiger tubes) and will detect a pulse as small as -0.25 volt at the Geiger tube wire. For manual operation, the X-ray intensity can be measured either over a fixed time interval or the time measured to count a predetermined number of pulses. The advantage of the latter method is that the probable error (for counting alone) is the same for each measurement but a long time is required at a low counting rate.

The rate meter has a fixed full-scale range and operates from any selected stage of the scaling circuit. Therefore

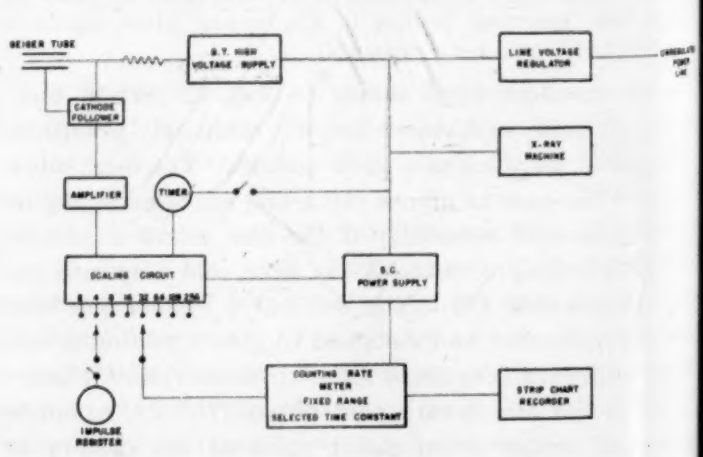

FIG. 4. Block diagram of circuits for Geiger tube operation.

each of the ranges is related to the other by an exact factor of two. A selector switch is provided to change the full-scale range from 50 to 40 or 30 cps, giving a total of 24 amplitude ranges with maximum counting rate of 12,800 cps. Five values of time constant (1 to 16 sec) are provided. The output of the rate meter can be read directly on a meter for survey work or recorded on a strip-chart recorder.

Intensity Calibration. Due to the limited resolving time of the Geiger tube and additional errors caused by automatic recording, it is necessary to calibrate the intensity measurement. This is easily done by means of a crystal plate and absorbing foils of equal thickness. The crystal plate is used in the specimen holder to monochromatize the beam. If a quartz plate (cut parallel to 10·1) and nickel foils (0.0007 in. thick) are used and the X-ray tube operated below 28 kvp, no difficulty will be caused by subharmonics ($\lambda/2$, $\lambda/3$, etc.) of the reflected beam. However, the calibration is accurate only for the kvp applied to the tube because the dead time of the Geiger tube measured in this way decreases with increasing kvp. Thus the difference in absorption of foils at the subharmonic wavelengths must be taken into account, or a crystal used having no reflection of higher orders.

For manual operation the intensity is measured with either the fixed count or fixed time method, depending upon the accuracy desired, for 1, 2 . . .*n* foils until the background is reached. The measured intensity in the form of counts per second is plotted on a logarithmic scale as a function of the number of foils on a linear scale. A straight line drawn through the points on the lower end of the intensity scale will then show where the measurements depart from linearity. For automatic operation the line is scanned from the same direction a few times for each number of foils and the average peak height is plotted instead of counts per second. A new calibration must be made if the scanning rate, time constant, amplitude range, or X-ray optics are changed, for these vary the measured intensity, peak position, and line shape. Unpublished work of Hamacher has shown that the peak counting rate is increased by a factor of two using full-wave rather than a half-wave rectified X-ray tube for the the same power input, and by three in operating the Geiger tube 300 v instead of 100 v above threshold.

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Two Radioactive Methods for Studying Certain Gas-Metal Reactions

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There are certain reactions between gases and metal surfaces yielding a solid reaction product which is deposited as a film over the surface of the metal. For example, the reactions between a clean aluminum surface and oxygen result in a thin oxide film spread over the metal surface. The usual method of studying the extent and rate of such film formation is the cumbersome and tedious "weight gain" technique. Two alternative methods, applicable to cases involving radioactive components, have been developed at K-25[1] for studying certain reactions of this type. These techniques, to be described, have proved extremely useful and convenient in studying the rate, the time dependence of the rate, the total magnitude of the reactions, and certain properties of the deposited films, and may have extension to other specialized investigations of similar nature.

Three criteria the particular reactions must satisfy for these methods to be applicable are: (a) The reacting gas must contain a radioactive component, (b) One product of the reaction must be a solid which adheres more or less firmly to the metal surface, and (c) The radioactive component of the gas must become a component of the solid reaction product. The number of reactions satisfying these requirements is not large, but such reactions are rather difficult to follow by regular methods.

An example of the type of reaction which may be studied by these methods is that which occurs between gaseous ruthenium pentafluoride and a clean metal surface, e.g., copper, under appropriate conditions. The pentafluoride is reduced to the nonvolatile trifluoride, which is deposited on the metal surface. The ruthenium may be obtained in a radioactive form (106) which emits beta particles at a satisfactory rate. Thus, all the stipulated requirements are met by this reaction.

Method 1. The metal involved in the gas-metal reaction to be studied is made into a Geiger-Müller or a proportional counting tube, say, 1 in. in diam and 10 in. long. A fine wire of the same metal (or alternately, of another metal inert to the gas involved), say 0.003 in. in diam, is suspended along the axis from insulators at the ends of the tube, to serve as the high voltage collector electrode of the counting tube. Suitable tubing, equipped with valves and filters, is provided for admitting and removing the corrosive gas.

The first step in studying a reaction is measuring the background counting rate, resulting from cosmic rays, contamination, etc. Then the radioactive, corrosive gas, suitably filtered, is admitted into the counting tube under the desired condition, left for a predetermined period of

[1] This work performed under contract No. W-7405-Eng-26 for the Atomic Energy Commission at Carbide and Carbon Chemical Corporation plant K-25, at Oak Ridge, Tennessee.

reaction with the metal of the tube, say 1 min, and then pumped out. After purging the tube with inert gas and filling with some suitable counting gas, such as methane, the amount of deposited nonvolatile radioactive product left in the tube is determined by the counting rate.

The radioactive gas may then be readmitted for another exposure period, and the amount of increase in deposit subsequently determined. In this way, one may measure the rate of reaction, and the variation of the rate, with different parameters.

It is obvious, o course, that any of the radioactive gas left in the tube at the time of counting, whether chemically reacted with the metal surfaces or physically absorbed thereon, contributes to the total radioactive count. This constitutes a disadvantage in that care must be exercised to outgas thoroughly the adsorbed gas before determination of the reaction extent. This constitutes an advantage also, however, in that knowledge of physical adsorption and factors like temperature governing the adsorption, often highly desired, is easily obtained. That is, it is often of great assistance in interpreting a reaction to know how the deposited film may be removed, or how it behaves in other ways, as well as the rate at which the reaction originally proceeded. In this way the effects on deposited radioactive films of extended evacuation, high temperatures, treatment with hydrogen, fluorine, etc., have been studied.

Method 2. The second method to be described has not been used as extensively as the first. It is, in fact, still in the developmental-calibration stage, but it seems to offer certain advantages for the study of particular reactions.

The metal involved in the gas-metal reaction to be studied is made into the form of a fine wire, say 0.005 in. in diam. The wire is wound into a loose coil and mounted inside a chamber, where exposure to the radioactive gas can occur under the chosen conditions. One end of the wire extends from the chamber into a suitably arranged "withdrawal alley," through which, at chosen intervals, short lengths of the wire may be removed as samples. The wire samples, removed at successive intervals after the start of the exposure, contain on their surfaces increasing amounts of radioactive deposit, proportional to the extent of reaction occurring before their removal from the exposure chamber.

The wire samples are mounted in succession along the axis of a suitably designed Geiger-Müller or proportional radioactivity counting tube, where they serve both as the source of radioactivity being measured and the ion-collecting electrode of the tube. By measuring the activity of similar samples receiving increasingly long exposures to the corrosive gas, a history of the reaction may be obtained.

Each of the methods described has certain advantages and disadvantages. With the metal of interest in the form of a counter tube, the same metal surface is intermittently exposed to the corrosive gas, with periods of evacuation and exposure to inert counting gas between corrosive gas exposure. Presumably, the intermittency of exposure and the effect of inert gas would have little influence on the gas-metal reaction being studied, but this would have to be established. The chief advantages of the method are: (a) the system, in contrast to the usual "weight gain" technique, does not have to be broken, with attendant likelihood of moisture contamination, etc., to permit periodic observations of the extent of the reaction; (b) once the system is set up, periodic observations of the extent of the reaction are quickly, easily, and reliably made; and (c) the exposure and counting system is easily set up, and with simple gas manifold and counter switching arrangement can handle many samples as easily as one.

With the metal of interest in the form of wire, individual samples are removed from the exposure chamber and not reused. The chief advantage is that the removal of a sample in wire form is easy to achieve without interrupting the course of the reaction on other samples left in the exposure chamber. Samples in the shape of disks, for example, would be extremely difficult to remove from an exposure chamber without interrupting the reaction, or opening the exposure chamber to ambient atmosphere, etc. Placing the wire sample in a clean, well-designed counter tube is rapidly accomplished, and gives suitable counting results.

Either of these methods, by adequate care in calibration, may be arranged to give absolute values of reaction rates. It is considerably easier to use the technique for obtaining relative values of the reaction rates between different metals and a given corrosive gas.

The most troublesome item to be encountered in the use of the methods described is the condition of the metal surfaces involved in the reaction. Extreme care in preparation of smooth, clean, uniform surfaces is necessary if reproducible data are desired.

Instrumental Methods of Studying Some Properties of Aerosols[1]

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The general properties of aerosols were recently described elsewhere by the author (*3*). These colloidal dispersions of liquid or solid particles in a gas are the most ephemeral and elusive of colloidal systems. Hence they have received less study than liquid-dispersed systems, although they comprise clouds and smokes, dusts and bacterial spores of great economic and practical, as well as theoretical, importance. Recent developments of instrumental methods allow rapid investigation of the mass

[1] The parts of this paper dealing with the research of the author and his collaborators are based on work done for the Office of Scientific Research and Development under Contract OEMsr-282 with Northwestern University, and for Camp Detrick, Frederick, Maryland, under Contracts WA-18-064-CWS-137 and -160 with Northwestern University and No. W-18-108-CM-31 with Indiana University.

concentration, number, and size of the dispersed particles, which will be outlined in this paper.

Many properties of aerosols may be studied by measuring the light which they scatter. Lord Rayleigh (*11*) in 1871 developed the theory of light scattering by very small particles, showing that it varies with the sixth power of the radius of the particle and inversely with the fourth power of the wavelength of the light, thus explaining the blue color of the sky and the red color of the sun near the horizon as resulting from selective scattering of the shorter wavelengths of sunlight by clouds, dust, and even the molecules of the atmosphere. In 1908 Gustav Mie (*10*) extended the theory to particles comparable with the wavelength of light and larger, showing that the scattering from these particles was chiefly in the forward direction, with a number of other maxima which increased with the size of the particle. This causes a series of spectra when white light passes through a *homogeneous* aerosol, as shown by V. K. LaMer and D. Sinclair (*9*), who counted the number of red bands between 0 and 180° to determine the size of the particles, since the number of spectra is practically equal to the radius in tenths of a micron. Particles too fine to show spectral orders show a regular change in polarization of light they scatter sideways, as the radius increases. LaMer and Sinclair developed a simple method of determining the size of homogeneous aerosols, based upon this fact.

Most liquid-dispersed systems are stable over long periods of time, while all but the most dilute aerosols change rather rapidly by settling and coagulation. Mass concentrations of the order of 100 μg/l, containing ten million particles or less, do not change appreciably in a few minutes, but their systematic study requires a continuous generator which can be controlled to put out a uniform concentration. In our laboratory, A. H. Peterson has developed such a mass concentration control, applicable to any aerosol of uniform particle size or constant particle size distribution. An aliquot of the aerosol is passed through a cell where it is subjected to strong dark field illumination. The scattered light is focused upon a photomultiplier tube and compared with a beam of the direct light from the lamp, attenuated by suitable filters to about the same level of intensity. This arrangement eliminates the effect of changing light intensity. The two beams, falling alternately upon the same part of the photomultiplier surface to insure uniform response, may be compared in rapid succession, or the direct signal may be used at longer intervals to standardize the gain of the photomultiplier, the output of which is amplified to control the diluting air and hence the mass concentration of the aerosol. The same system can be used to measure, as well as control, the mass concentration. In either case, to avoid recalibration of the apparatus when a new lamp is inserted and the optical system is cleaned, we find that the light scattered by an organic vapor such as ether is sufficient to serve as an internal standard.

An earlier apparatus for measuring aerosol concentrations, developed in our laboratory by H. B. Pickard and C. T. O'Konski (*2, 4*) collects the light scattered at right angles by the aerosol and focuses it upon a vacuum photocell. The photocurrent, passing through a very high resistance, gives a voltage drop which is measured potentiometrically, using a single vacuum tube amplifier with a balanced plate circuit and galvanometer as a null indicator. This instrument, sensitive to $5 \cdot 10^{-9}$ lumen or 10^{-3} μg/l of dioctyl phthalate aerosol of 0.3 μ diam, was used as a direct-reading penetration meter, capable of testing the best respirator filters.

Photoelectronic methods of counting individual aerosol particles and thus determining particulate concentrations were developed in our laboratory by C. T. O'Konski, H. B. Pickard, and J. N. Pitts, Jr. (*7*), and have been evaluated by R. N. Ferry, L. E. Farr, Jr., and Mary G. Hartman (*1*). The aerosol flows through a cell under intense dark field illumination, the pulses of light scattered in the forward direction are collected upon a thalofide or photomultiplier cell, the resulting electrical pulses are amplified, and those above any desired value actuate a thyratron trigger tube and a mechanical counter. This allows the counting of spherical particles down to about 0.5 μ diam, or of spores of *Bacillus globigii*, which are ellipsoidal, averaging $0.8 \times 0.8 \times 1.2$ microns, at rates up to about 1000 per minute. Later work by C. T. O'Konski (*6*) in this laboratory, using an improved optical system, reduced the background light to the point where three-quarters of it came from the scattering of the air molecules in the 7-mm³ illuminated space viewed by the phototube. This apparatus, now being tested by D. G. Rose, should be capable of counting at considerably higher rates, using an electronic counter or rate meter. It also has a differential pulse amplitude selector, designed to count the pulses within a predetermined voltage range and thus allow the rapid determination of particle size distribution. If the light field is sufficiently stable and uniform, the apparatus should classify particles 1 μ in diam or larger into 1-μ-size range groups with a resolution of 5 or 10%.

An electrostatic method of counting particles 2.5 μ or more in diam and of determining their size distribution was developed by A. C. Guyton (*8*). The aerosol is sucked through a hole 0.8 mm in diam to impinge upon a charged collecting plate or wire. The individual particles produce electrical pulses, the voltages of which are proportional to the squares of the particle diameters. With a suitable electrical discriminator, this apparatus provides a convenient and rapid method of determining particle size distribution in the range over which it is applicable. A discussion of the theory of this counter and a comparison with the photoelectronic type has been given by C. T. O'Konski and the author (*5*).

Another method of determining particle size distribution under investigation in our laboratory by George J. Doyle involves a measurement of the amplitude of vibration of individual particles of a moderately dilute aerosol in an intense sonic field. Very light particles vibrate with the full amplitude of the air molecules, while very heavy particles are not affected by the sound. For any particular frequency there is a range of particle size over which the amplitudes are spread out enough to allow a determination of the size distribution, at least for spherical

particles which obey the Stokes-Cunningham law. Intense dark field illumination of the particles allows photography of a number of vibrating particles in a small fraction of a second. Our present apparatus employs standing waves of 5-kc frequency, generated by the type of oscillator described by H. F. St. Clair (*12*), and is applicable to particles from 1 to 5 μ in diam, while a 40-kc frequency will cover the range from 0.1 to 1 μ.

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A Contact Modulated Amplifier and Some of Its Laboratory Uses

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Developed to measure d-c signals on the order of a few hundredths of a microvolt, this amplifier employs motor-driven contacts to modulate the input signal (*2*). It features ruggedness, portability, stability, low noise level, and insensitivity to vibration.

Direct-current input signals are converted to a-c (80 cycles) by means of a mechanical breaker, stepped up in voltage by a transformer, amplified with several vacuum tube stages, and finally rectified by another breaker driven synchronously with the input breaker. This arrangement reduces the effect of random variations in the amplifier and favors the wanted signals introduced at the input.

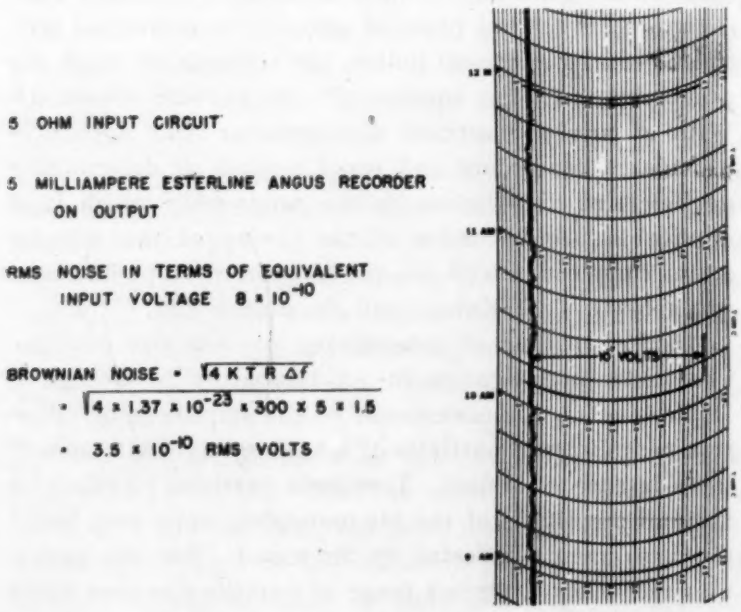
5 OHM INPUT CIRCUIT
5 MILLIAMPERE ESTERLINE ANGUS RECORDER ON OUTPUT
RMS NOISE IN TERMS OF EQUIVALENT INPUT VOLTAGE 8 × 10⁻¹⁰
BROWNIAN NOISE = √(4 K T R Δf)
= √(4 × 1.37 × 10⁻²³ × 300 × 5 × 1.5)
= 3.5 × 10⁻¹⁰ RMS VOLTS
10⁻⁹ VOLTS

FIG. 1. Amplifier noise level and drift over a 3-hr period.

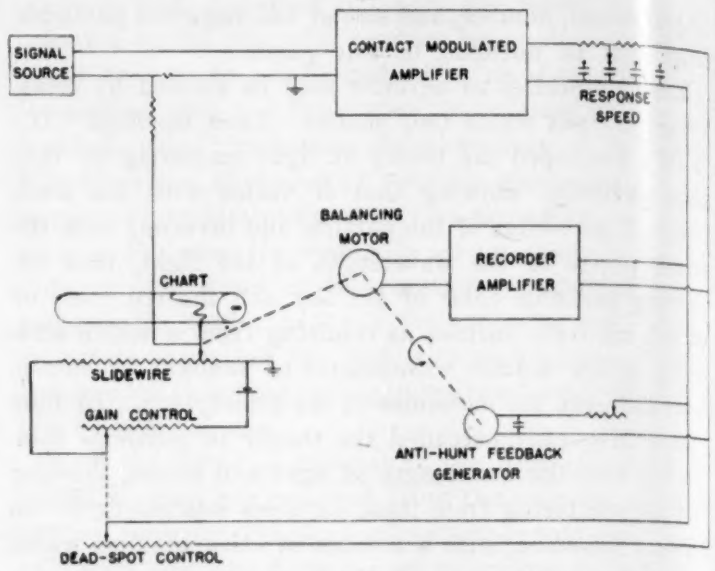

FIG. 2. Infrared spectrograph recording circuit.

Drift due to small temperature differences between components in the input circuit has been minimized by careful construction and selection of materials. Thermoelectric coefficients of the copper components in this part of the amplifier are matched and junctions are soldered with a special solder (70% Cd, 30% Sn) having a low thermo emf with respect to copper. The input transformer is magnetically shielded with multiple, concentric layers of Mumetal and soft iron.

Fig. 1 shows a performance record of the amplifier. A test signal of 10^{-7} v applied to the 5-ohm input circuit provides calibration from which the random noise level can be measured. An interesting comparison is made in Fig. 1 between the observed noise of 8×10^{-10} rms v and the Brownian noise due to thermal agitation in the input circuit. In the expression for Brownian noise:

K = Boltzman constant
T = Temperature in degrees Kelvin
R = Resistance of input circuit
Δf = Over-all band width (cycles) of amplifier and recorder.

The observed noise is only a little more than twice the theoretical minimum.

This amplifier has found one of its most important applications in the field of infrared spectroscopy. It is

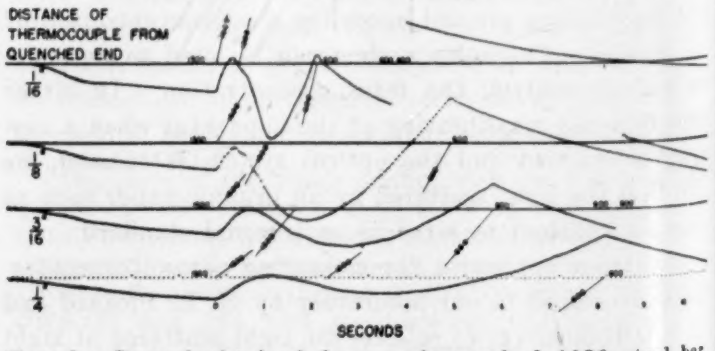

FIG. 3. Record obtained from end-quenched 1020 steel bar.

used with a variety of recording circuits (*4*) in several types of infrared spectrographs. The recording circuit shown in Fig. 2 employs the amplifier as a preamplifier

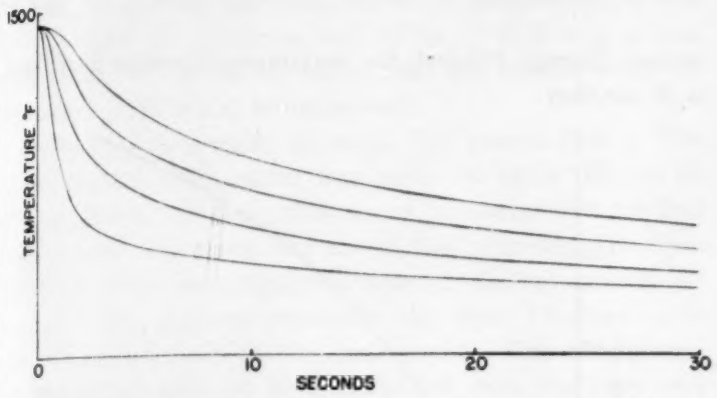

FIG. 4. Cooling curves as recomposed from data of Fig. 3.

for a self-balancing potentiometer type recorder. The features provided are: null balance, wide range of gain control, selection of response speed or band width, and antihunt control. A degree of sensitivity with stability is obtained which permits the recording of infinitesimal quantities of energy on recording instruments of the type commonly used in severe industrial surroundings such as steel mills and foundries.

In a system for studying quench processes in the heat treatment of steel, the amplifier is used with another recording circuit. Time-temperature cooling curves produced by thermocouples at four different locations on a steel bar are recorded during a quench. A method is employed wherein only small differential signals are recorded so that all four curves can be obtained simultaneously on a chart of convenient size while using high sensitivity for accuracy. The major portion of the signal from each thermocouple is bucked out by an opposing emf, which is continuously varied, approximately to cancel the thermocouple signal. During the initial rapid cooling period of the quench, the bucking signal is reduced linearly by a potentiometer driven synchronously with the drum carrying the chart. Fig. 3 shows the first ten sec of a quench record made in this manner. Zero time, as indicated on the time axis (horizontal) of the record, marks the beginning of the quench. The traces prior to zero time represent the cooling of the test bar as it was brought from the 1500° F furnace to the quenching bath. After completion of a quench the actual cooling curves as shown in Fig. 4 are obtained by combining the recorded difference deflections with the bucking signals employed. Cooling rates up to 1200° F per sec have been recorded.

In the oxyhemograph (*1, 3*), a device for recording directly the percent oxygen saturation of the hemoglobin of the blood, photocell signals are applied to the contact modulated amplifier. A photocell, placed on the opposite side of the pinna of the ear from a small light source,

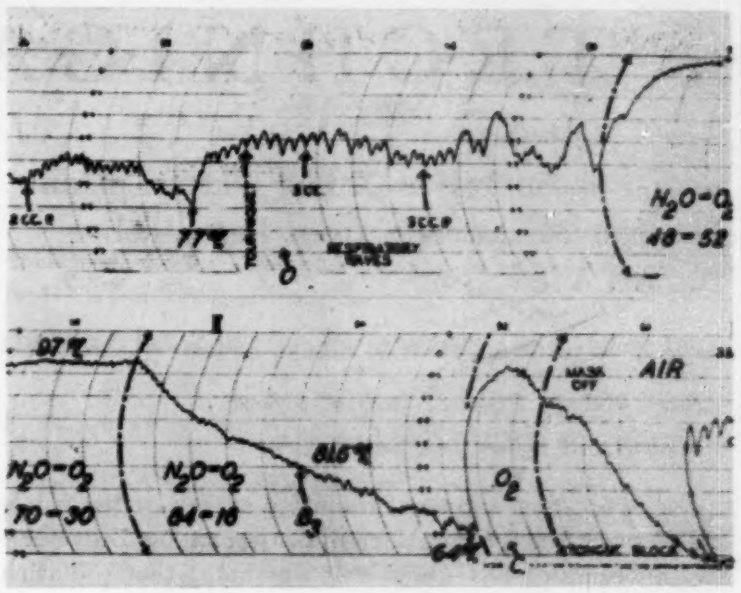

FIG. 5. Oxyhemograph record made with patient under anesthesia for surgery.

responds to changes in the light-transmitting property of blood, which varies with the percent oxygen saturation of the hemoglobin. The oxyhemograph has been found especially useful in the operating room during anesthesia for surgery. Fig. 5 shows sections of a record made in the operating room of the Henry Ford Hospital. The time between each vertical line on the chart is 30 sec. The upper edge of the chart represents 100% oxygen saturation of the blood, the lower edge 60%; below 60% is a dangerously low oxygen content. Each peak in the record on the top section of chart represents one respiration of the patient. The general level of blood oxygen content is low here (lowest point 77%), due to the action of the anesthetic. However, it is increased subsequently by permitting the patient to breathe a mixture of nitrous oxide and oxygen. It was learned, early in the work with the oxyhemograph, that strain on the patient is lessened if the blood oxygen saturation is maintained near normal (95%) during the operation.

The bottom section of the chart shows how the patient's changing condition during the final critical phases of the operation is quickly reflected by the instrument. Blood oxygenation values fluctuate so rapidly and so widely that intermittent gas analysis determinations are inadequate.

The amplifier has found many other uses where high sensitivity is required in the neighborhood of vibration and disturbance.

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TECHNICAL PAPERS

Radiation Survey of X-Ray Output of an Electron Microscope from Personnel Hazard Viewpoint[1]

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In performing a general radiation survey of the physical plant of the Atomic Energy Project at the University of California at Los Angeles, it was noted that radiation well above background levels existed in the vicinity of the 50-kv electron microscope. Since a portion of the electron beam strikes various metal surfaces in the 'scope, continuous X-rays are generated. It is possible for the operator of the electron microscope to be exposed to this radiation through the various viewing apertures. The presence of this X-radiation from the electron microscope initiated a survey of the instrument for possible hazards.

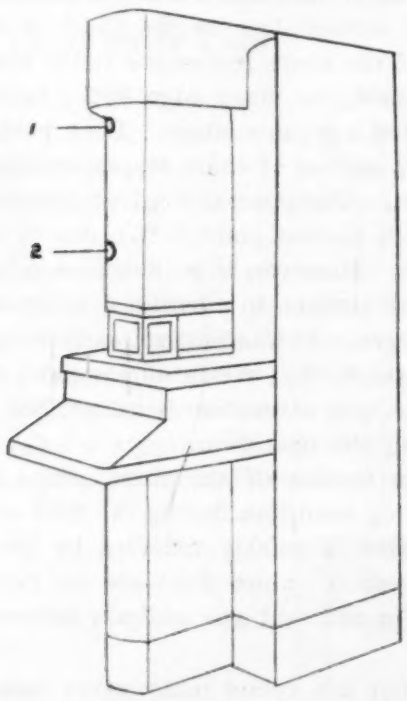

FIG. 1.

A calibrated Keleket dosimeter was placed so that the sensitive volume was in direct contact with the port of the primary viewing screen, (1 in Fig. 1). With the beam current of the electron microscope at 200 μa, the average dosage at this port was approximately 1500 mr/hr. If a person were exposed to this level a full working day, he would receive several hundred times the maximum permissible exposure. The dosage at the intermediate viewing port, (2 in Fig. 1), was 70 mr/hr. At this

[1] This report is based on work performed under Contract No. AT-04-1-GEN-12 between the Atomic Energy Commission and the University of California at Los Angeles.

Atomic Energy Project, the maximum exposure permitted is 50 mr/day.

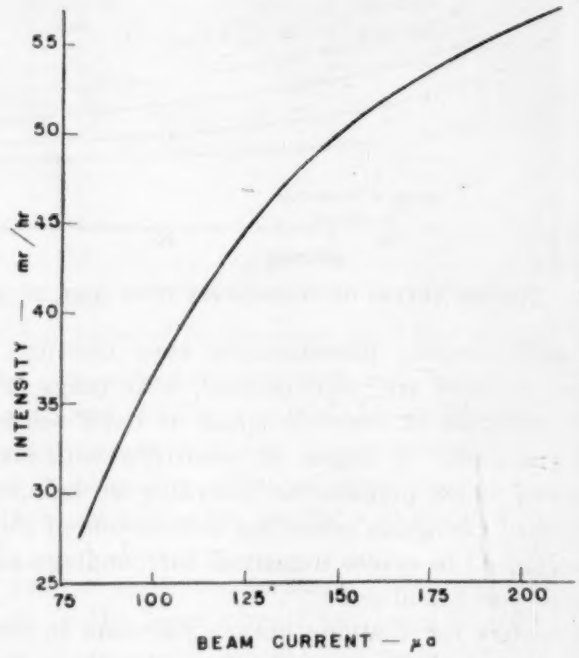

FIG. 2. Dosage vs. beam current at 20 cm.

The intensity of the X-rays was measured as a function of the beam current in the electron microscope. This was done by using a Victoreen Model 356 survey meter placed so that the nylon window of the ionization chamber was 20 cm from the port of the primary viewing screen. The data are shown in Fig. 2. The beam current commonly employed ranges from 100 to 300 μa. At 200 μa the dosage at 20 cm would be about 56 mr/hr, which is approximately ten times the tolerance rate.

The hardness of the X-ray beam was determined by making a series of measurements with Al filters. Fig. 3 shows the results of these determinations.

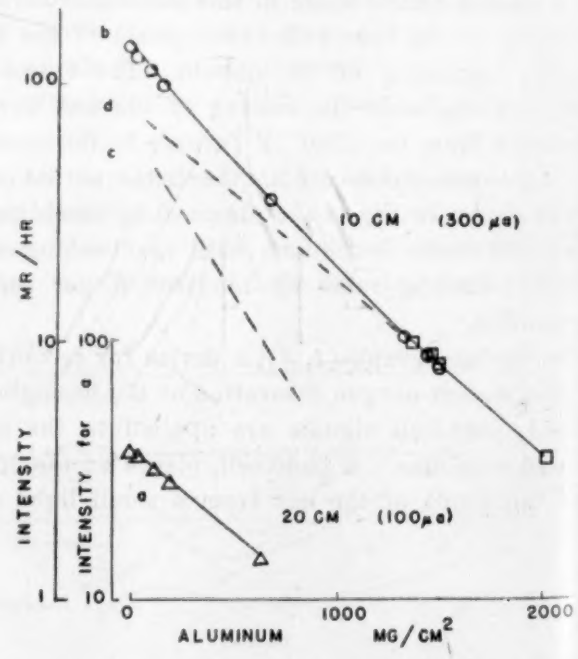

FIG. 3. Attenuation of X-rays from electron microscope.

Curve (a) is a graph of the X-ray intensity in mr/hr plotted against the thickness of Al filter in mg/cm². These data were obtained by using the Model 356 meter. The beam current for this series of measurements was 100 μa, and the distance was 20 cm. This was a convenient set of values to use so that the middle range of the instrument could be employed.

Curve (b) is similar to curve (a) except that a Victoreen Model 247A meter was used. A beam current of 300 μa and a distance of 10 cm were convenient for this instrument. In curve (b) the circles represent the data obtained with the aluminum case of the instrument removed. The squares represent the data obtained with the aluminum case on the instrument. The consistency of these two sets of data indicated that the case was equivalent to 1.34 g/cm² of Al filter. In plotting the squares, this equivalent filter weight was added to the actual weights of the filters used.

The range of attenuation in curve (b) is sufficient to show a decrease in the slope of the curve with increasing weight of the Al filter. This change of slope is due to the fact that the softer components of the X-rays are filtered out more quickly than the more penetrating hard components remaining in the X-ray beam. To obtain an approximate estimate of the proportion of soft and hard components, curve (b) was analyzed in the usual way producing curves (c) and (d). Curve (c) represents the more rapidly attenuated soft component, and curve (d) the harder component. Since the X-rays are of the continuous type arising from the bombardment of bronze in the electron microscope by 50-kv electrons, the division of the X-rays into two components, hard and soft, is just a convenient approximation and is an empirical representation of the data.

Mass absorption coefficients, μ_m, computed from the slopes of the curves (a), (c), and (d) are tabulated:

Curve	μ_m *in cm²/g*	*Distance in cm*
(a)	1.5	20
(c)	2.5	10
(d)	1.5	10

This corresponds to half-value thicknesses of Al of 1.0 and 1.7 mm for the soft and hard components respectively. Apparently the X-rays at 20 cm from the port of the primary viewing screen are qualitatively like the hard component of the beam at 10 cm. Using standard tables for the mass absorption coefficient of Al, this set of values corresponds to a wavelength range of 0.45–0.50 A for the X-rays. This is approximately the wavelength range in which one may expect to find the peak energy for a continuous X-ray spectrum arising from 50-kv electrons (*1*).

A ¼-in.-thick plug of lead glass was placed in each viewing port. The dosage at the ports was then reduced to less than 1 mr/hr. The high dosage had been due to the accidental use of ordinary glass instead of lead glass in the assembly of this instrument by the manufacturer.

It is suggested that electron microscopists survey the radiation from the viewing ports to determine whether or not the X-ray intensity exceeds the accepted tolerance dosage.

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Airborne Magnetometer for Measuring the Earth's Magnetic Vector

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An airborne instrument which continuously records geomagnetic information from which all magnetic components may be determined has been developed at the Naval Ordnance Laboratory. The instrument is a modified form of the airborne total field magnetometer developed by the Naval Ordnance Laboratory and Bell Telephone Laboratories during World War II for the location of submerged submarines by the detection of their anomalous fields. Since the war, this submarine detector, with slight changes, has been used for geophysical prospecting.

The basic feature of the new magnetometer is that it now determines the total magnetic field vector instead of only the intensity. This is done by measuring the intensity and the direction of the total magnetic field vector with respect to a set of coordinate axes stabilized with respect to the surface of the earth.

The sensitive measuring element of the magnetometer is a saturable inductor which is excited by a 1000-c current of sufficient amplitude to saturate its permalloy core. A 2000-c voltage is generated by the inductor, the amplitude of which is proportional to the strength of the magnetic field along its axis. The inductor is mounted in a gimbaled arrangement driven by servo motors to maintain its detection axis parallel to the earth's magnetic field. The gimbaled arrangement with its servo motors is called the detector head and is secured to the frame of the aircraft. Potentiometers and their associated electronic circuits measure the amount of angular displacement of the detection element about the two axes of the gimbals in which the detector is carried. By means of these angles the total magnetic field vector can be projected onto a system of coordinate axes fixed with respect to the aircraft.

In order to make use of these data, the orientation of the aircraft with respect to vertical and true north must be determined. A vertical reference is provided by a gyroscope controlled by gravity-actuated devices so as to maintain the spin axis of the rotor of the gyroscope vertical. Potentiometers on the roll and pitch axes of the gyroscope measure the inclination of the aircraft with respect to vertical. These angular measurements are used to refer the magnetic data to a coordinate system stabilized with respect to the surface of the earth.

The true heading of the aircraft is obtained by periodic astral observations. A continuously recording directional gyroscope maintains a record of the aircraft heading between astral observations. The position of the aircraft is determined by one or a combination of astral observations, loran fixes, radar, visual observation, and photography, depending upon the area to be surveyed.

During flight the total magnetic field intensity, the aircraft heading, and the angular displacements about the gimbal axes of the detector head and the gyro vertical are continuously recorded by graphic milliammeters. The process of determining the various magnetic quantities from these data is carried out after the flight is completed.

The vertical reference gyroscope used to measure the inclination of the aircraft is subject to certain errors so an alternate system for establishing a vertical reference was developed employing an oil-damped pendulum. The pendulum will produce true readings only when the aircraft is in a state of nonaccelerated flight. The directional and vertical gyroscopes are used, therefore, to ascertain when the accelerations due to changing attitude are at a minimum. Points are selected during these periods for computing the magnetic quantities.

In order for the magnetometer to be employed to the greatest advantage, a stable aircraft and smooth flight conditions are required.

Charts showing the components of the earth's magnetic field are issued periodically by the Navy Hydrographic Office and the U. S. Coast and Geodetic Survey. The angle of declination or magnetic variation is of primary importance because of its requirement for navigational purposes. The other components, angle of dip, total intensity, and vertical and horizontal fields were formerly of more or less academic interest but are now finding increasing use in specialized fields of research, development, and geophysical exploration.

Up to the present time, the great bulk of magnetic surveys for chart-making purposes have been conducted employing instruments consisting of rotating coils or the deflection and oscillation of small magnets. Although these instruments are capable of highly precise measurements on the ground, they have not been particularly adaptable for use in aircraft for the determination of the earth's complete magnetic field vector. They also require that surveys be conducted on a point-by-point basis, which is time-consuming.

Surveys of oceanic areas have been made with similar types of instruments and have required the use of nonmagnetic ships. Such measurements were terminated in 1929 when the only existing nonmagnetic vessel, the "Carnegie," burned off the island of Samoa. Similar to ground measurements, the data taken at sea is a point-by-point process with one set of observations made each 200 to 300 miles. Measurements made at sea, however, were less accurate than those made on land.

The airborne measurements are expected to be of the order of accuracy of those made at sea. The airborne surveys, however, will have the advantage of greater speed, continuous recording, and the avoidance of small magnetic anomalies near the surface of the earth.

Due to the constantly changing nature of the earth's magnetic field, the problem of tying a large number of observations made at widely separated times to a common time base should be considerably simplified with the use of airborne instruments due to the fact that vast areas may be mapped in a short period of time.

At the present time the magnetometer is limited to operation in areas of dip angles of about 50° and greater. With additional development the range of operation can be extended to all areas of the earth. Only one instrument has been constructed, and it is undergoing flight tests at the present time.

Avoiding Trial-and-Error in Infra-microscopic Photography[1]

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The phenomenal surge of interest in the general field of photography that preceded World War II was not followed as closely as might have been expected by a corresponding development in photomicrography. New lenses and other factors produced an infinite variety of "close-ups" achieved with techniques which were used to scientific advantage but were pursued largely as a hobby, to obtain unusual patterns in subject matter. The field of photomicrography scarcely developed in these years beyond the needs of those who required the technique for teaching purposes or to illustrate scientific publications.

Strictly speaking, this was true of America more than of Europe, owing, perhaps, to the available equipment there, particularly that of German origin. For some years before the war even the person who pursued photomicrography as a hobby was accustomed to replacing the lens of his Leica with a suitably threaded adapter, which contained a shutter and an indirect-vision aperture and which fitted, in turn, the eyepiece of the microscope. In this instance all three elements—the camera, the adapter, and the microscope—were manufactured by the same firm, Ernst Leitz of Wetzlar, although adapting devices were generally available for most cameras. Much of the work in America was, and still is, accomplished by connecting the camera to the microscope by means of a flexible sleeve, often an automobile radiator hose. While excellent photographs can be obtained with this simple device the technique has certain serious disadvantages, particularly in regard to stability and variable focusing, difficulties which now can be remedied with several types of standard equipment.

Between the range of the close-up and that of true

[1] Use of this particular camera does not imply its endorsement by the U. S. Public Health Service.

photomicrography there lies another field of invaluable and fascinating photography which invites further exploration: the photomagnification of objects grossly visible to the naked eye. It is a range that may be defined as that lying between the scope of normal human vision at 10 in. and that of actual low power photomicrography.

FIG. 1. Alpa reflex camera mounted for close-up photography.

In some European technical literature the range has been defined as "macrophotography" (also, and more correctly, "photomacrography") although we may quarrel with the use of these terms, which specify all photography below the microscopic range. Perhaps the term "inframicroscopic photography" might describe this undefined area. As a functional field it chiefly covers the study of surface structure, animate or inanimate, and was first introduced in popular photography in terms of such subjects as razor blade edges, cactus spine points, and insect wings. The technique rapidly became a valuable scientific tool in all spheres, from botany to ballistics.

Certain unique problems face the scientist or hobbyist who pursues photography in this range, particularly if the material to be studied varies in texture, translucency, color, or depth. These difficulties are unique because they greatly exceed those found in either normal photography or photomicrography, where lighting and focusing are more constant factors. With these problems specifically in mind, cameras and accessories have been devised to meet the requirements of this highly variable intermediate range.

The Swiss-made Alpa-Reflex is one of these cameras, with precision accessories cleverly contrived to fill the needs of every range of photography from infinity to microscopic. It is literally an all-purpose, 35-mm miniature camera (24 × 36 mm) ideally suited to general outdoor photography and to photomicrography, as well as to the perplexing inframicroscopic field. Equipped with mirror reflex focusing, eye-level view finder, complete range finder, and a standard 5-cm coated lens, the flash-synchronized focal plane shutter allows time exposures as well as a scale extending from 1 sec to 1/1000 sec. A small but valuable feature is that the exposure setting can be read at any time, since the setting knob does not rotate when the shutter is released. Coated and color-corrected lenses with focal lengths 3½–18 cm are available and can be easily adjusted, being fixed in bayonet mounts. Unusually long helical screws of 20-mm range permit exceedingly close-up focusing with ease. To adapt the camera to photomicrography nothing more is needed than a clamping ring which fits—or can be ordered to fit—the extension tube of any microscope, while a complete survey of the microscopic image is provided by the ground glass screen in the reflex view finder.

It is the intermediate field of the so-called macrographs to which the Alpa-Reflex is particularly suited (Fig. 1). It must be remembered that in photographing objects that are in one plane, as a smooth surface, a lens of standard focal length should be used in preference to a wide-angle lens. In three-dimensional subjects a better perspective is produced by increasing the focal length of the standard lens. The reproduction ratio should be selected with the size of the ultimate enlargement in mind. All surfaces have a limit in the degree of possible magnification, beyond which further detail is lost, a definite limit of resolvability beyond which no more finite detail can be distinguished. In the case of three-dimensional objects, where the depth of the field is the essential factor, only the questions of perspective and lighting determine the focal length, since the depth of focus is the same for the reproduction ratio regardless of the focal length.

Such problems, which may be exasperatingly difficult to solve with improvised equipment, particularly when color film is used, are reduced to a minimum with supplementary lenses. To begin at the scale of normal photography, the standard focal length 5-cm lens, having a 3-mm range of adjustment, allows a focus ranging from infinity to 1 meter. To focus under 1 meter, extension tubes usually are provided with a +1 D supplementary lens to cover the gaps in range left as the result of using the tubes. However, the function of the main lens is considerably impaired by supplementary lenses; hence the desirability of using interchangeable lenses of greater focal length (7½–18 cm), in which case the usual supplementary lenses of shorter focal length are unnecessary. The intermediate tubes provide a continuous range of supplementary extension.

The versatility of this equipment, designed with the problems of inframicroscopic photography in mind, obviates the discouraging and wasteful trial-and-error methods of focusing and lighting and justifies the initial expenditure.

Improvements in the Making of Special Photographic Emulsions for Nuclear Physics

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Institut de Physique, Université de Montréal

In 1945 (1) the author prepared concentrated, very fine-grained emulsions such as emulsion formula 2 (*2*), in which it has proved possible to record, with good detail and discrimination, the tracks of fission fragments (*3*), alpha rays, protons, and even of slow electrons (*1, 2*). Experience has shown us that the properties of these emulsions are hot easily reproduced (*4*). The critical factors have been found to be: the mechanical and stoichiometric conditions during the mixing operation; the temperature of the wash water, which should be preferably below 5° C; and the gelatine used.

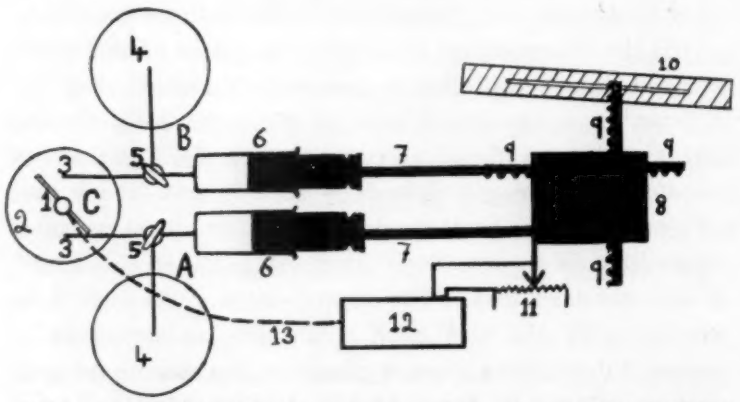

FIG. 1. Schematic view from above of emulsion-making machine. Sliding parts are shown in heavy black. Part 1 represents a stirrer; 2, a beaker containing solution C; 3, pouring tips; 4, tanks of solutions A and B; 5, three-way stopcocks; 6, 100-ml syringes; 7, pushing rods; 8, sliding carriage (bench carrying 8 and motor moving it are not shown); 9, right angle racks sliding inside 8 and linked through pinion (not shown); 10, sheet with slot guiding the movement of racks 9; 11, potentiometer regulating speed of motor 12; 13, flexible shaft from motor 12 to stirrer 1.

To control mechanical and stoichiometric factors, a machine has been designed and built that is illustrated schematically in Fig 1. To the stirred C solution, solutions A (600 g $AgNO_3$/1000 ml solution) and B (420 g KBr/1000 ml of solution) are added simultaneously, through the action of syringes, pushing rods, and carriage, moved by a motor sliding along a bench. Volumes of solutions A and B are kept constantly equivalent or nearly so, B being in slight excess. The double rack mechanism with its guiding slot introduces an adjustable difference between the movements of the pistons of syringes containing A and B, and thus allows one to cope with a difference of diameter between pistons, and with inaccuracies of concentrations of A and B. Also, through the peculiar shape of the slot chosen, it is possible to vary the excess (B-A) at will during mixing. The system also fills up syringes when they are empty. Here are numerical data for solution C: 15 g gelatine, 167 ml water, and 83 ml ethyl alcohol; use at 40–50° C. First add 1.3 ml of B. Then deliver at equivalent rates 100 ml of A and B, taking 2–3 min. Increase the stirring rate from 240 to 550 rpm. Chill and set at 0–2° C (1 hr). Break the jelly in small pieces and wash at 0–2° C (1 hr). Collect, melt, coat, dry, and sensitize 1 min in 6% triethanolamine before use.

In this method, the mixing phase is highly critical but there is no high temperature treatment. In preparing ordinary emulsions, mixing may be less critical but the heat treatment is a delicate phase.

This machine has been used with uniformly good results. A prototype of it, using 30% syringe sizes and quantities in mixing, has been in operation for nearly a year with consistently good results. Under its standardized conditions, 13 gelatine samples have been tried, and all gave good tracks of alpha rays and protons, and at least a peculiar granular appearance with radium D electrons. The best electron tracks (40–60 kv) resulted from gelatines labeled "fast negative," that is, from gelatines recommended for obtaining the greatest light sensitivity.

This gives us further reason to believe that similar active centers are essential both for light and for ionizing particles. Still unexplained is the lack of connection noted between light and particle sensitivity for various emulsions, which probably depends on the disposition of active centers on the AgBr grains.

This work was supported by the National Research Council, and a detailed report of it will be sent to the Canadian Journal of Research.

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Sensitivity of Gamma-Ray Counters[1]

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Radioisotopes can be investigated in many cases only by detection of their gamma radiation. Measurements of the distribution and the amount of an isotope used for tracer studies or for therapeutic purposes are often based on counting the gamma rays emitted in a certain direction (*3*). The sizes of source and gamma-ray counter, and the distance between them, determine the fraction of the total gamma radiation which is incident on the detector. The actual number of registered counts is again only a fraction of the incident gamma rays, depending on the sensitivity of the counter. It is known that even counters made from high atomic material detect only 0.7–2% of the gamma rays with energies between 0.5–3.0 Mev when the gamma radiation penetrates the counter walls perpendicularly (*2*). This low counter sensitivity is a serious limitation for many investigations. Different methods which result in a higher counting sensitivity will be outlined here.

Somewhat higher sensitivities can be obtained by using

[1] Supported in part by a grant from the Office of Naval Research.

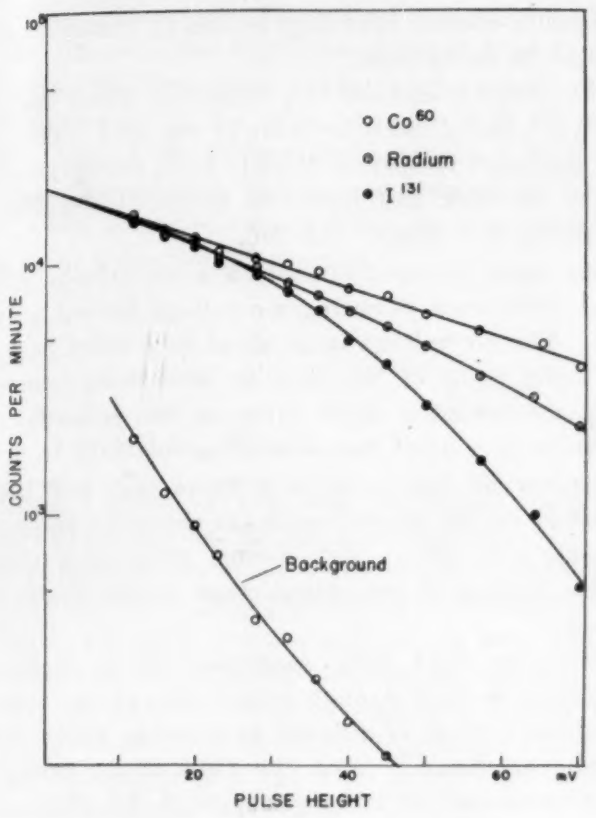

FIG. 1.

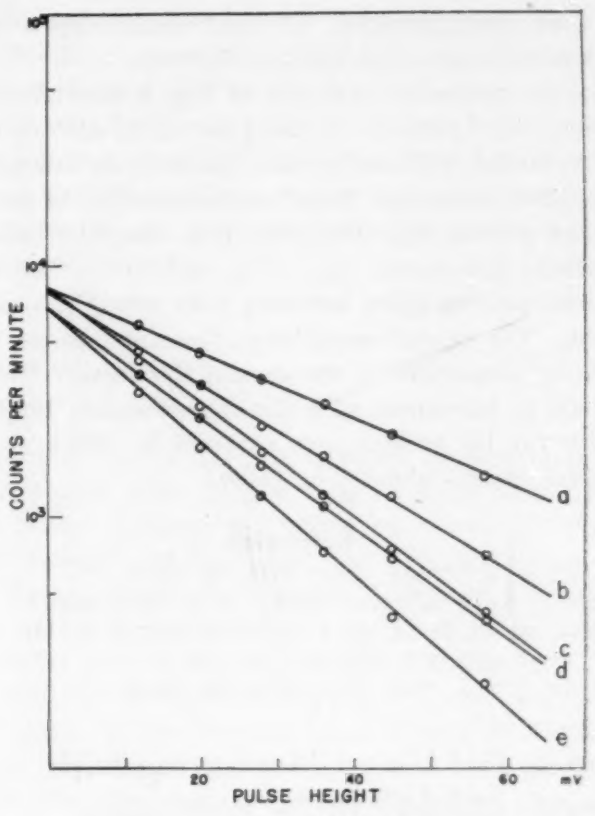

FIG. 2.

Geiger-Müller counters end-on. The probability for the secondary electrons, produced by the gamma rays in the counter walls, to enter the sensitive volume of the counter increases when the gamma rays strike the walls at a small incident angle. With calibrated I^{131}, Co^{60}, and radium sources, sensitivities of about 2% for I^{131}, and 4% for Co^{60} and radium were observed with commercial end-window tubes, such as the North American Philips No. 62019. The same results were obtained with a multicellular type of counter.[1]

A large number of organic and inorganic crystals have come into use recently as scintillation counters (*1, 4*). The gamma rays absorbed in the crystal produce light flashes, which are detected and amplified by a photomultiplier tube. Due to their high density and high atomic weight components, calcium tungstate crystals show a very high gamma-ray sensitivity. Under conditions described herein, sensitivities of 24%, 38%, and 36% for Co^{60}, radium, and I^{131} gamma rays, respectively, were observed, with highly polished, clear crystals[2] of area $\frac{1}{2} \times \frac{1}{2}$ in. and thickness $\frac{1}{8}$ in.

A 1P21 photomultiplier tube operating at about 90 v per stage and the $CaWO_4$ crystal were kept at room temperature. A model 500 Los Alamos preamplifier and discriminator, together with a scaling circuit, counted photomultiplier pulses greater than 12 mv. Fig. 1 shows the counting rate versus integral pulse height for Co^{60}, Ra, and I^{131} sources. The tube background, also given in Fig. 1, has been subtracted from the source measurements, which were adjusted to the same extrapolated counting rate. The three curves indicate the differences in gamma-ray spectra of the three isotopes.

[1] U. S. Patent #2,397,661, The Texas Company.
[2] The Linde Air Products Company, Tonawanda, N. Y.

Taking into account only the primary gamma rays entering the crystal through its front surface ($\frac{1}{2} \times \frac{1}{2}$ in.), the percent crystal sensitivities mentioned were obtained. For the $\frac{1}{8}$ in.-thick $CaWO_4$ crystal, the sensitivity for I^{131} corresponds to the expected gamma-ray absorption in the crystal. However, the Co^{60} and Ra sensitivities are at least twice that expected from the absorption of the incident primary gamma rays alone. Since these results were found to be independent of the resolving time of the counting equipment, which was varied from 5 to 300 μsec, the $CaWO_4$ crystal used under these conditions caused no double pulsing.

All three pulse height distributions of Fig. 1 were obtained with a Lucite rod, 1 in. in diam and 4 in. long, placed between the crystal and the photomultiplier tube. The $CaWO_4$ crystal was covered with an Al foil as reflector, except for the surface touching the Lucite rod. Fig. 2 shows how the radium pulse height distribution is affected by varying this arrangement.

Curve (a) of Fig. 2 repeats the results with the radium source given in Fig. 1. Curve (b) was obtained when the Lucite rod was removed and the crystal was mounted directly on the photomultiplier tube but without being covered with Al foil. The decrease in large pulse heights shows that the light absorption in the Lucite is smaller than the amount of light gained by the Al foil. Curve (c) shows a further decrease in light intensity when the Lucite rod was again placed between crystal and photomultiplier but without using the Al foil reflector.

All three curves intersect at about the same extrapolated counting rate. This indicates that the results were not affected by a change of the crystal arrangement when the extrapolated counting rates were used. The application of the Lucite rod provides a better geometry

for most investigations. Its replacement by a quartz rod would improve the light conduction.

Finally, curves (d) and (e) of Fig. 2 show the results for the crystal placed with the $\frac{1}{8}$ in. $\times \frac{1}{8}$ in. surface facing the Lucite rod, with and without Al foil. In this position the surface area and therefore the number of incident primary gamma rays was only $\frac{1}{4}$ as compared with the conditions for curves (a), (b), and (c). The extrapolated counting rates, however, were nearly the same as before. The crystal sensitivity, therefore, seems to increase in proportion to the crystal thickness. These results are in agreement with the approximately 100% sensitivity for Ra gamma rays reported by Moon (*4*), for a $CaWO_4$ crystal about $\frac{3}{8}$ in. thick.

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3. Hill, R. F., Hine, G. J., and Marinelli, L. D. *Amer. J. Roentg. rad. Therap.*, in press.
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Adapter For Visual Monitoring with Portable Geiger-Müller Equipment

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New England Deaconess Hospital, Boston

The application of a neon-filled strobotron (SN4) tube as a visual means of continuous monitoring of areas in which radioactive materials are used has proved itself very convenient.

Fig. 1 is the schematic diagram of a circuit developed for using an SN4 (manufactured by Sylvania Electric Company) as a visual indication of instantaneous changes in counts, that may be due to contamination or changes in background.

The circuit is enclosed in a metal box which has a large bull's-eye lens directly in front of the SN4. This circuit was developed to operate directly from the earphone jack of the Herback and Rademan Geiger-Müller Radiation Measuring Set, Model GLR-200.

The signal is superimposed on a d-c voltage which in effect produces a pulsating d-c voltage having a positive sign. The d-c voltage is adjusted to a value just below the firing point of the OA4 by sensitivity control R7. Thus, the incoming signal increases the potential of the d-c value to a point that will cause this tube to fire.

Resistor R6 has to be of a value that will keep the potential on the starter anode at the same value as the cathode, and yet of high enough value to prevent excessive loading of the output stage of the Geiger-Müller circuit.

When the OA4 fires, condenser C2 is momentarily shorted to ground through resistor R4, at the same time the plate voltage is reduced to a value which will not support operation. With the OA4 in an extinguished state, condenser C2 recharges through R5, thus impressing a positive voltage of sufficient value on the starter anode of the SN4 to cause it to fire. The SN4 will become extinguished when the potential of C1 falls below the critical operational potential. Following these events C1 becomes recharged through R1, thus conditioning the circuit for another firing sequence.

The operation of the circuit is dependent upon the height of the voltage pulse from the output stage of the Geiger-Müller circuit. This pulse must have a value of not less than 5 v.

The sensitivity of the instrument is directly dependent upon the Geiger-Müller tube used and the preliminary cir-

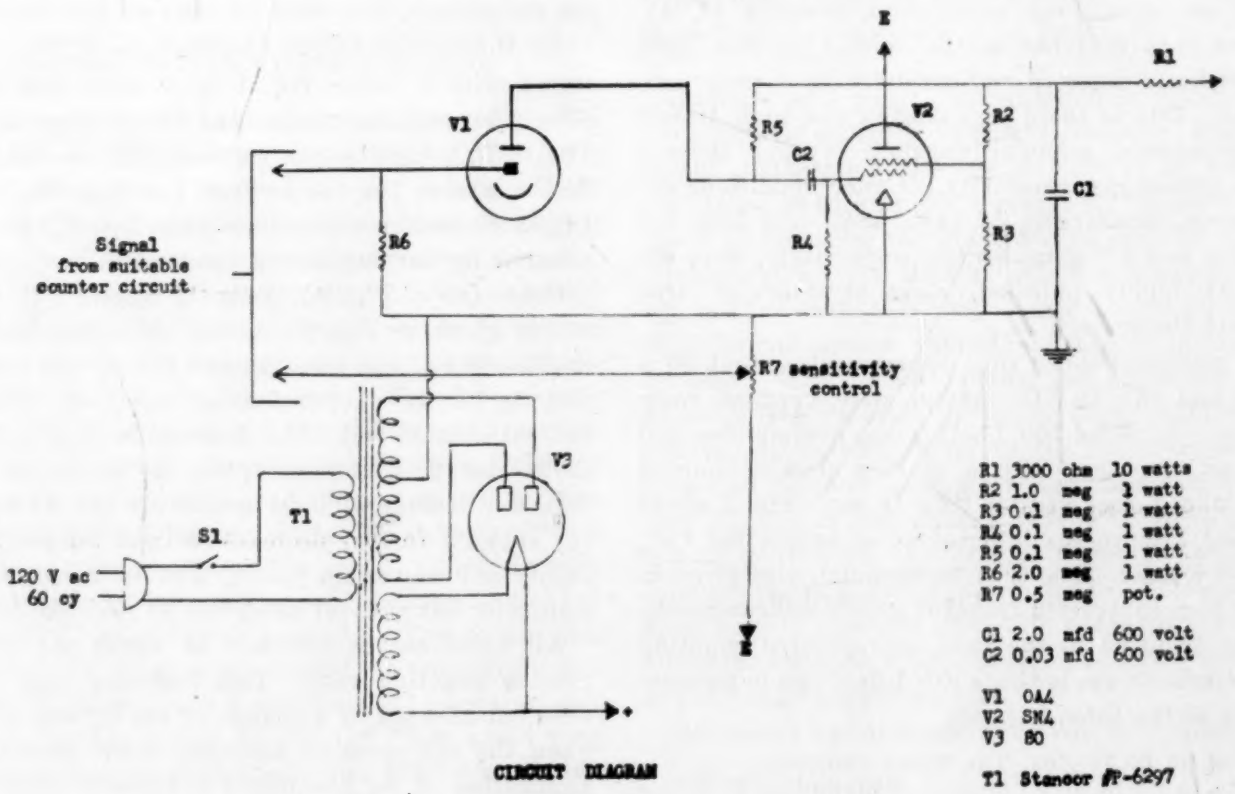

FIG. 1.

cuit. In our laboratory a Radiation Counter Laboratory Type 10A Beta-Ray Counter Tube obtained from Tracerlab, Boston, Massachusetts, having a glass wall of 30 mg/cm², or about 0.12 mm thick, is used. With the setup described, 3 μc of P^{32}, I^{131}, and Ra salts give a flash rate about twice background, at a source distance of 25 cm.

The OA4 tube was selected as it has characteristics that require small wattage for operation.

As the pulse sequence of the circuit is very short, having a duration of a few microseconds, the SN4 was selected for its very high illuminating intensity.

No attempt has been made to develop a quantitative measuring instrument, as the primary requisite is for detecting infinitesimal amounts of radioactive substances on clothing, hands, glassware, sinks, and counter tops around the laboratory.

(*Continued from page 352*)

summarized a paper by Van Lear and Long, describing an American commercial Raman spectrograph.

Other physical measurement methods were described by Madame Y. Cauchois, of the Laboratory of Physical Chemistry, Paris, who gave two papers—one on new developments of bent crystal techniques and one on curved crystal X-ray spectroscopy. In the same section A. Guinier, also from Paris, talked about demountable tubes and cameras for X-ray crystallography and some recent techniques in X-ray metallography.

Among the mechanical measurements discussed were two methods for photographic recording of ultrahigh speed phenomena by explosions, described by C. H. Johansson, of Detoniklaboratoriet, Stockholm. In one, instantaneous photographs are taken with an ordinary camera, using sparks or flash lamps as light source and a Schlieren apparatus. By repetition, lighting at successive time intervals being reckoned from the start of the explosion, quantitative measurements of the velocity at different stages of the occurrence can be made. Intervals from 2 to 500 microseconds are obtained by a detonation fuse. Other papers in this section included one by Robert Schnurmann, of the Manchester Oil Refinery, Ltd., England, on lubricant testing methods, and one by Pierre Piganiol, of the St. Gobain Company, Paris, on the measurement of the melt viscosity of plastic materials.

In the division of industrial control, R. S. Medlock, of the British firm George Kent, Ltd., spoke on the analysis of oxygen, based on its paramagnetic properties. With the exception of nitric oxide, oxygen appears to be the only strongly paramagnetic gas, and this affords a physical method of measurement. Other lectures included two by W. F. Hanson, of the Du Pont Company, and Maurice Surdin, chief of electrical construction services for the French Atomic Energy Commission.

Papers on metrology included one by Rene Yribarren, of Société d'Application de Metrologie Industrielle, Paris, who spoke on "Some Considerations About Accurate Fits." He described the contribution of the Solex air-operated method to the present problems of industrial metrology. All of the apparatus he described had the same object, he said—to incorporate inspection within the machining department, and to make measuring techniques formerly used for judging into guides for production. Other papers were read by A. Metz, of Ernst Leitz, Wetzlar, Germany, and Karel Veska, of Kovo Ltd., Prague, Czechoslovakia.

As part of the conference, a fairly large exhibit had been arranged, with a floor area of more than 30,000 square feet. Among the exhibitors were the French Atomic Energy Establishment, the French Defense Research Establishment, the German East Zone, and several of the main instrument manufacturing firms in Sweden. The greater part of the exhibit was commercial.

Perhaps the most interesting part of the exhibit was that arranged by the Swedish State Council of Technical Research in cooperation with the Academy of Engineering Sciences and the Association of Technical Physicists. Here was shown instrumentation research under way in Swedish institutions and laboratories. The committee on large computing machines showed parts from their project on a binary relay machine.

Other computing machines shown at the exhibit included an analogue computer for aircraft stability problems, an automatic recording Fourier synthesis apparatus, and parts from a mechanical differential analyzer with four integrating units, under construction at the Chalmers Institute of Technology.

New developments of direct-reading pH-meters, usable for all types of potentiometric measurements, and polarographs with a maximal sensitivity for full-scale diffraction of 0.0033 microamperes were shown by the Chemical Institution of the University of Upsala.

The Department of Telegraphy and Telephony at the Royal Institute of Technology had a wide range of apparatus, among which may be mentioned an automatic impedance meter for automatic recording of locus diagrams of networks within the range of 100 to 15,000 kilocycles per second, a heterodyne filter that can be used as a band-pass filter with continuously variable high and low frequency cutoff, that has an attenuation of 1 to 2 cycles per decibel.

In the field of electronics the Department of Electronics at the Royal Institute of Technology showed a 37-Mev synchrotron and a new development of the trochotron for pulse counting. The counting rate of a scale built with this new tube is 10 megacycles per second.

The Department of Electronics at Chalmers Institute of Technology showed experiments on radio wave propagation, a radar search for meteors, and the latest development in the traveling wave tube.

By special invitation, the U. S. National Bureau of Standards, the National Research Council of Canada, the RCA Research Laboratories and the Bell Telephone Laboratories had arranged booths in this part of the exhibit.

NEWS and Notes

D. B. Anderson, professor of plant physiology and assistant director of the Graduate School at North Carolina State College, has been made head of the Department of Botany, effective September 1.

Otto A. Reinking, professor and head of the Division of Plant Pathology, New York State Agricultural Experiment Station, Cornell University, has just returned from a research trip on diseases of abaca which took him to Tawau, British North Borneo, and Davao, Philippine Islands.

Douglas M. Kelley has resigned his position as associate professor of psychiatry and director of the Psychiatric Hospital at the Bowman Gray School of Medicine, Wake Forest College, to become professor of criminology at the University of California, Berkeley. Dr. Kelley will give courses in criminologic psychiatry and detection of deception.

Wilhelm Spannhake, senior scientist at the David Taylor Model Basin, Bureau of Ships, Washington, D. C., has joined the staffs of Armour Research Foundation and the Graduate School of Illinois Institute of Technology. Dr. Spannhake is the author of *Centrifugal pumps, turbines, and propellors; basic theory and characteristics.*

T. P. Ting, of the Department of Biology at Amherst College, has been appointed research associate professor of physiology at the University of Saskatchewan. Dr. Ting will conduct radiobiological research with the 25-Mev betatron recently developed at the University of Saskatoon.

Arthur J. Bedell, professor emeritus of ophthalmology, Albany Medical College, will deliver the fourth William Hamlin Wilder Memorial Lecture of the Institute of Medicine of Chicago at a joint meeting with the Chicago Ophthalmological Society on October 14. His subject will be "Medical Ophthalmology: A Kodachrome Demonstration of Fundus Photographs of Diabetes, Hypertension, Nephritis, Optic Neuritis, and Choked Disc."

Walsh McDermott, associate professor of medicine, Cornell University Medical College, will deliver the third William Allen Pusey Memorial Lecture of the Institute of Medicine of Chicago at a joint meeting with the Chicago Society of Internal Medicine on October 28. His subject will be "Antimicrobial Therapy."

Hartmut Kallmann, former professor of physics at the Technische Hochschule in Berlin-Charlottenburg and head of the Department of Physics at the Kaiser Wilhelm Institute at Berlin-Dahlem, has been appointed professor of physics at New York University. Dr. Kallmann will continue his research on the scintillation counter, conductivity-counting, and fluorescence.

Charlotte Moore-Sitterly, of the National Bureau of Standards' spectroscopy laboratory, has been elected an associate of the Royal Astronomical Society of Great Britain. Dr. Sitterly was honored for her contributions in the fields of astronomy and astrophysics, particularly her extensive compilations of multiplet tables and her work in identifying lines in solar and sun spot spectra. She is the first woman to receive this distinction, although the late Annie J. Cannon, of the Harvard College Observatory, was an honorary member of the society.

Visitors to U. S.

Herman M. Kalckar, research professor of the University Institute of Cellular Physiology, Copenhagen, will deliver the first Harvey Lecture of the current series at the New York Academy of Medicine on October 27. Dr. Kalckar will speak on "Enzymatic Reactions in Purine Metabolism."

C. F. Tipper, of the Engineering Laboratory, Cambridge, England, is dividing ten weeks in this country between work on strength of metals at the Naval Research Laboratory, Washington, D. C., and visits to other scientific laboratories. During and following the war, in addition to her teaching at Cambridge University, Dr. Tipper worked on deformation and fracture of practical engineering metals. She will lecture on "Correlation of Test Results" at the Metals Congress in Cleveland on October 19.

Grants and Awards

The Max Planck medal for scientific achievement was awarded on September 23 to Lise Meitner, of the Royal Swedish Academy of Sciences in Stockholm, and Otto Hahn, professor at Gottingen University. The medal, which is the highest award of the German Society of Physicists, was presented at Bonn University, Germany.

The Franklin Medal, highest honor given by the Franklin Institute of Pennsylvania, will be presented this year to Theodor H. E. Svedberg, director of the Gustaf Werner Institute for Nuclear Chemistry, Upsala, Sweden. The medal, which will be presented October 19 in a ceremony at the institute, is in recognition of Dr. Svedberg's development of the ultracentrifuge in determining molecular weights and other achievements in the field of colloid chemistry. Former winners of the medal include Thomas A. Edison, Guglielmo Marconi, Albert Einstein, and Sir Robert Robinson.

Fellowships

The Life Insurance Medical Research Fund will accept applications for 1950 grants-in-aid of cardiovascular research up to *January 1, 1950.* Approximately $550,000 will be awarded in support of physiological, biochemical, and pathological research bearing on cardiovascular problems, as well as for clinical research in this field. Preference is given to fundamental research.

At least 12 postgraduate fellowships between $3,000 and $4,000 are also available for research training, with larger amounts available in special cases. An M.D. or Ph.D. degree, or the equivalent, is required and applications for 1950–51 will be accepted up to *January 1.* A number of predoctoral fellowships for basic training in research will also be awarded. Applications and fur-

ther information may be secured from the Scientific Director, Life Insurance Medical Research Fund, 2 East 103 Street, New York City 29.

Colleges and Universities

Wayne University will present its sixth annual lecture series, "Frontiers of Chemistry," cosponsored by the International Society of the Friends of the Kresge-Hooker Library, on consecutive Monday evenings, beginning October 10. Lecturers and their topics will be: *Charles Smyth*, Princeton University Physics Department, "Molecular Orientation and Dielectric Behavior in Liquids and Solids"; *W. Conard Fernelius*, Department of Chemistry, Pennsylvania State College, "Some Current Problems in the Structure of Coordination Compounds"; *N. H. Furman*, Department of Chemistry, Princeton University, "Electrical Methods of Chemical Analysis"; *Paul D. Bartlett*, Department of Chemistry, Harvard University, topic to be announced; *Lee Irvin Smith*, School of Chemistry, University of Minnesota, "The Chemistry of Some Cyclopropanes"; *A. L. Lehninger*, Department of Surgery, University of Chicago, "The Enzymatic Oxidation of Fatty Acids"; *Maurice L. Huggins*, Research Laboratories, Eastman Kodak Company, "Properties of Long-Chain Compounds"; and *D. C. Grahame*, Department of Chemistry, Amherst College, "Progress and Problems in the Study of Electrical Double Layer."

The noncredit registration fee for the series is $5.00 and checks, made payable to Wayne University, should be mailed to J. Russell Bright, chairman of Wayne's Chemistry Department. Qualified persons may arrange for graduate credit of one or two hours.

The University of Cincinnati has opened a new psychosomatic ward at Cincinnati General Hospital. Patients will be admitted with high blood pressure, stomach ulcers, asthma, diabetes, colitis, or other ailments not completely explained by physical causes. The new ward will aid in training and research in psychosomatic medicine. Maurice Levine, head of the university's Department of Psychiatry, and M. A. Blankenhorn, head of the Department of Internal Medicine, will be directors of the new ward.

Meetings and Elections

The Conference of Professors of Preventive Medicine will hold its annual meeting October 24 at the Hotel Statler, New York City. Health officers, personnel from graduate public health fields, and other interested persons are invited to attend. Programs are available upon request from Leland W. Parr, George Washington University Medical School, Washington, D. C., or from David Rutstein, Harvard Medical School, Boston.

The International Congress of Military Medicine and Pharmacy will be held October 23–29 in Mexico City. Maj. Gen. Raymond W. Bliss, Army Surgeon General, and his deputy, Maj. Gen. George E. Armstrong, will participate in the program, and several scientific papers will be presented by Army, Navy and Air Force delegates.

The Indiana Academy of Science will hold its fall meeting November 3–5 at Wabash College, Crawfordsville, Indiana. Papers will be presented in the 11 divisions of the academy. C. L. Porter, of Purdue University, will give the presidential address.

A symposium on water problems of the process industries will be held by the **New York Section of the American Institute of Chemical Engineers** on November 17 at the Hotel Statler, New York City. Topics to be discussed include substitution of air or seawater for surface water cooling towers, water treatment to reduce sealing, applications of compression distillation, and a survey of the economics of supplying water to the plant.

The American Society of Ichthyologists and Herpetologists elected the following officers at its 29th annual meeting: John Treadwell Nichols and Helen T. Gaige, honorary presidents; M. Graham Netting, president; George S. Myers, F. H. Stoye, and Fred R. Cagle, vice presidents; Edward C. Raney, secretary; Lionel A. Walford, publications secretary; and Dwight A. Webster, treasurer.

The 295th meeting of the **American Physical Society** will be held at the University of Chicago, November 25–26. Sessions of invited papers will be presented by the Divisions of Electron Physics and of Solid-State Physics. Hotel headquarters will be the Sherman Hotel and members should make their reservations by letter to Miss Ruth Brown, Sherman Hotel, Randolph at Clark Street, Chicago.

Deaths

Frederick MacAllister, 74, retired professor of botany at the University of Texas, died in Austin on January 7. At the time of his death, Dr. MacAllister was preparing a monograph on the mosses and liverworts included in his extensive collection.

Alonzo E. Taylor, 78, pathologist and internationally known agricultural economist, died May 20 at his home in Palo Alto after a short illness. Dr. Taylor joined the Stanford Food Research Institute as director in 1921 and resigned as director emeritus in 1936. Much of his time was devoted to research in the international relations of food supplies.

Robert Gordon Sinclair, 46, Craine professor of biochemistry at Queen's University, Kingston, Ontario, Canada, died August 17 as the result of a swimming accident in Lake Ontario. Dr. Sinclair had been at Queen's since 1937 and had previously held the rank of associate professor of biochemistry at the University of Rochester. He was well known for his basic studies on the metabolism of phospholipides.

John D. Long, 75, traveling representive of the Pan American Sanitary Commission, died in Guayaquil, Ecuador on September 18. Dr. Long was formerly director of health in the Philippines, chief quarantine officer of the Panama Canal Zone, vice director of the Pan American Sanitary Commission, and vice president of the Far Eastern Tropical Medicine Institute.

Cobb Pilcher, 44, brain surgeon, and associate professor of neurosurgery at Vanderbilt University Medical School, died September 22 of a heart attack. Dr. Pilcher had conducted extensive research in the treatment of Jacksonian epilepsy and brain infections, and in work with vascular lesions of the nervous system.

The Oak Ridge Institute of Nuclear Studies will present three additional basic courses in the techniques of using radioisotopes as tracers this winter. They will be held January 2–27, January 30–February 25, and March 6–31, 1950. Thirty-two participants will be accepted for each course. Application for the January 2 course should be mailed prior to *December 1.*

Each session is divided into laboratory work, lectures on laboratory experiments, general background lectures, and special topic seminars. Experiments will be conducted covering the use and calibration of instruments and the purification and separation of radioactive materials from inert materials and from other radioactive materials. Other laboratory work will be devoted to the application of various radioisotope techniques.

Seminar topics include the use of tracers in animal and human experimentation, design of radiochemical laboratories, dosimetry, instrumentation, the effects of radiation on living cells, and the principles and practices of radiation protection.

A registration fee of $25.00 is charged for each participant. Hotel or dormitory facilities are available in Oak Ridge.

Application forms and additional information may be obtained from Dr. Ralph T. Overman, Chairman, Special Training Division, Oak Ridge Institute of Nuclear Studies, P.O. Box 117, Oak Ridge, Tennessee.

The National Research Council's **Committee on the American Type Culture Collection,** which was appointed to study the problems of adequate financial support of the ATCC, has recommended increasing the price of cultures to make the maintenance and distribution of the collection cultures self-supporting.

The ATCC has been supported since its beginning by gifts as well as by sales. With continually rising costs the new policy was considered preferable to requesting gifts annually from industry. The price increase will be much less for educational institutions, in keeping with the ATCC's objective to provide an essential service to microbiology.

Beginning January, 1950, the price of cultures will be ten dollars each, with a discount of 70% to educational and charitable institutions, and to organizations or individuals whose activities primarily concern the public welfare.

The National Research Council committee is continuing its studies to insure permanence to the collection and to increase its usefulness.

The American Society of Zoologists, which meets December 28–30 with the AAAS in New York City, has extended its deadline for demonstration program papers to *October 25.* Papers should be sent to the secretary, Walter N. Hess, Hamilton College, Clinton, New York.

The ***South African Journal of Science,*** formerly a yearly volume of papers read at the annual congress of the South African Association for the Advancement of Science, has begun monthly publication. The new journal will no longer be confined to the publication of material presented at the annual meeting of the association, but will print short articles and comments on current affairs, letters to the editor, reports of meetings, and book reviews.

A provisional advisory committee on science abstracting for Unesco during the year following the publication of the report of the International Conference on Science Abstracting will be composed of: *S. Bhagavantam,* scientific liaison officer, India House, London; *Pierre Bourgeois,* director, Bibliotheque Nationale Suisse, Bern; *Verner W. Clapp,* chief assistant librarian, Library of Congress, Washington, D. C.; *J. E. Cummins,* chief scientific liaison officer for Australia, Africa House, London; *G. M. Findlay,* editor, *World Abstracts,* London; *H. R. Kruyt,* Technische Natuurwetenschappelijk Onderzoek, Netherland; *L. H. Lampitt,* chairman, Bureau of Abstracts, London; *Bertil Lindblad,* director, Stockholms Observatorium, Saltsjobaden, Sweden; *Miguel Ozorio de Almeida,* director of the Department of Physiology, Institut Oswaldo Cruz, Rio de Janeiro; and *Jean Wyart,* Faculté des Sciences, Paris.

Make Plans for—

Seminar for the Study and Practice of Dental Medicine, October 23–28, Desert Inn, Palm Springs, California.

American Society for Horticultural Science, October 26–28, Milwaukee, Wisconsin.

A conference on mechanisms and evaluation of antiseptic activity, sponsored by the Biology Section of the New York Academy of Sciences, October 28–29, New York Academy of Sciences, New York City.

Second Annual Nucleonics Symposium, sponsored by the Institute of Radio Engineers and the American Institute of Electrical Engineers, October 31–November 2, Hotel Commodore, New York City.

Status of AAAS Meeting Reservations

The early and heavy demand for *single* rooms already indicates a potential shortage of this type of accommodations at the **116th Meeting of the AAAS in New York City,** December 26–31. There are plenty of hotel rooms but many have double or twin beds. Miss Sylvia T. Peltonen, Manager, Housing Bureau, New York Convention and Visitors Bureau, 500 Park Avenue, New York 22, who is in charge of room assignments, urges that, when possible, room reservations be placed by parties of two or more. This also has the advantage of a lower cost per person. Room reservation coupons will appear in the advertising pages of *Science* at frequent intervals.